Digitized by the Internet Archive
in 2023

https://archive.org/details/annalsofmissouri0003vari_3

ANNALS
OF THE
MISSOURI BOTANICAL GARDEN

Annals
of the
Missouri Botanical Garden

Volume III
1916

With Nine Plates and Eighty-four Figures

Published quarterly by the Board of Trustees of the
Missouri Botanical Garden, St. Louis, Mo.

Entered as second-class matter at the Post Office at St. Louis, Missouri, under the
Act of March 3, 1879.

Annals
of the
Missouri Botanical Garden

A Quarterly Journal containing Scientific Contributions from the Missouri Botanical Garden and the Graduate Laboratory of the Henry Shaw School of Botany of Washington University in affiliation with the Missouri Botanical Garden.

Editorial Committee

George T. Moore — Benjamin M. Duggar

Information

The Annals of the Missouri Botanical Garden appears four times during the calendar year, February, April, September, and November. Four numbers constitute a volume.

Subscription Price - -	$3.00 per volume
Single Numbers - - -	1.00 each

The following agent is authorized to accept foreign subscriptions:
William Wesley & Son, 28 Essex Street, Strand, London.

STAFF
OF THE MISSOURI BOTANICAL GARDEN

Director,
GEORGE T. MOORE.

BENJAMIN M. DUGGAR,
Physiologist, in charge of Graduate Laboratory.

HERMANN VON SCHRENK,
Pathologist.

JESSE M. GREENMAN,
Curator of the Herbarium.

EDWARD A. BURT,
Mycologist and Librarian.

J. C. TH. UPHOF,
Assistant Botanist.

GEORGE W. FREIBERG,
Research Assistant.

KATHERINE H. LEIGH,
Secretary to the Director.

BOARD OF TRUSTEES
OF THE MISSOURI BOTANICAL GARDEN

President,
EDWARDS WHITAKER.

Vice-President,
DAVID S. H. SMITH.

EDWARD C. ELIOT.
GEORGE C. HITCHCOCK.
P. CHOUTEAU MAFFITT.
EDWARD MALLINCKRODT.
LEONARD MATTHEWS.
WILLIAM H. H. PETTUS.
PHILIP C. SCANLAN.
JOHN F. SHEPLEY.

EX-OFFICIO MEMBERS:

EDMUND A. ENGLER,
President of the Academy of Science of St. Louis.

FREDERIC A. HALL,
Chancellor of Washington University.

HENRY W. KIEL,
Mayor of the City of St. Louis.

BENJAMIN P. STROMBERG,
President of the Board of Public Schools of St. Louis.

DANIEL S. TUTTLE,
Bishop of the Diocese of Missouri.

E. F. FINNEY, Assistant Secretary.

TABLE OF CONTENTS

		PAGE
Rhizoctonia Solani in Relation to the "Mopopilz" and the "Vermehrung-spilz"	B. M. Duggar	1 – 10
The Texas Root Rot Fungus and Its Conidial Stage	B. M. Duggar	11 – 23
Cabbage Yellows and the Relation of Temperature to Its Occurrence	J. C. Gilman	25 – 84
Monograph of the North and Central American Species of the Genus Senecio—Part II	J. M. Greenman	85–194
New or Interesting Species of Gill Fungi from Missouri	L. O. Overholts	195–200
A New Senecio from Jamaica	J. M. Greenman	201–202
The Thelephoraceae of North America. VI.	E. A. Burt	203–241
The Occurrence in Nature of Certain Yeast-like Fungi with Reference to Their Possible Pathogenicity in the Higher Animals	W. H. Emig	243–307
The Missouri Agrimonies	B. F. Bush	309–318
The Thelephoraceae of North America. VII.	E. A. Burt	319–343
Catalogue of the Plants of Jasper County, Missouri	E. J. Palmer	345–401
Pistillaria (subg. Pistillina) Thaxteri, Burt n. sp.	E. A. Burt	403–406

TABLE OF CONTENTS

		PAGE
A Note on the Adaptability of the Folin Micro-Kjeldahl Apparatus for Plant Work	A. R. Davis	407–412
Studies in the Physiology of the Fungi. I. Nitrogen Fixation	B. M. Duggar and A. R. Davis	413–437
Studies in the Physiology of the Fungi. II. Lenzites saepiaria Fries, with Special Reference to Enzyme Activity	S. M. Zeller	439–512
General Index to Volume III		513–517

Annals
of the
Missouri Botanical Garden

VOL. 3 FEBRUARY, 1916 No. 1

RHIZOCTONIA SOLANI IN RELATION TO THE "MOPOPILZ" AND THE "VERMEHRUNGSPILZ"

B. M. DUGGAR
Physiologist to the Missouri Botanical Garden, in Charge of Graduate Laboratory
Professor of Plant Physiology in the Henry Shaw School of Botany of Washington University

Discussing in a recent paper ('15) the distribution of *Rhizoctonia Solani* Kühn (*Corticium vagum* B. & C.) I made the following statements:

> "It is rather surprising to find that *R. Solani* has received relatively little attention in Europe. Although recognized as inducing a disease of the potato widely distributed in central Europe, and occasionally reported on the beet, yet little careful work has been bestowed upon the fungus."

I shall now endeavor to show, as definitely as a discussion of the literature will permit, that this statement requires material modification. At the same time the evidence indicates a considerable extension of the region in which this *Rhizoctonia* is important as a seed-bed parasite. The new light on the problem is a result of the provisional determination—amounting almost to a certainty—that the Javanese "Mopopilz" and the central European "Vermehrungspilz" are identical with *Rhizoctonia Solani* (*Corticium vagum* B. & C.).

Some years ago the writer attempted to determine the possible relation of *Rhizoctonia* to seed-bed or cutting-bench diseases in Germany, but at that time the literature was scant and confusing, so that the effort was unfortunately abandoned, largely, however, as a result of the suggestions from several sources, that *Pythium, Botrytis,* and other known forms were

clearly responsible for these diseases. It now appears that a considerable literature has been gradually accumulating, but it was not correlated with the work on *Rhizoctonia*, proceeding at the same time, owing largely to incorrect determinations. I owe the present outlook upon the literature to the illuminating paper of Rant ('15[a]) in which, it would seem, from his description and figures, that he clearly and correctly identifies the "mopo" fungus of Cinchona seed-beds in Java as *Moniliopsis Aderholdii*, described by Ruhland ('08) and designated by him as the cause of seed-bed and propagation-bed difficulties. It was necessary for me to go but a step further to determine that *Moniliopsis Aderholdii* is in reality identical with *Rhizoctonia Solani*. It seems well, however, to review briefly all the contributions thus far found which seem to shed light on this fungus as a cause of disease in propagating-beds, as studied in Europe and in Java, especially as it serves to supplement the literature cited in my recent paper (Duggar, '15).

Since comments will be made in connection with the review of literature, it may be well to emphasize certain characteristics particularly distinctive of *Rhizoctonia Solani*, and among those important are the following:

(1) The great variety of higher plants affected; (2) the rapidity of spread where seedlings are attacked, presenting an appearance as if hot water had been poured over the young plants; (3) the growth of a web of mycelium over the fallen plants and likewise over the adjacent soil, so that fragments of soil adhere when the plants are lifted;[1] (4) mycelium practically hyaline when young, with characteristic branching and septation, becoming brownish with age; (5) under favorable conditions, especially in culture, the development of floccose masses, consisting of chains of cells (Monilia-like), often much branched or elbowed, colorless to brownish; (6) the formation of dark brown sclerotial bodies, irregular in size and outline, developing in the same way as the floccose masses, but denser by anastomosis, with the form of the cells (in mature sclerotia) practically uniform throughout, that is, with no dif-

[1] This perhaps more than any other characteristic enables gardeners to distinguish the fungus from the effects of *Pythium* and of *Botrytis*.

ferentiated peripheral layer; and (7) cultures readily obtained from mycelium or sclerotium, the organism producing in culture only mycelium, flake-like masses or tufts, and effuse sclerotia.

In reviewing the earlier of these studies upon diseases of this type which may be caused by *Rhizoctonia* it is hazardous to attempt to interpret those cases in which the organism is inadequately described, yet bearing in mind the more striking characteristics of *Rhizoctonia*, it is believed that no literature is here included which does not suggest this fungus. In the later studies the organism has been for the most part so well described that little doubt may be entertained with respect to the determination. For the present it is necessary to rely upon a discussion of the literature, but when more material, in the form of cultures, from the regions here referred to is available, a supplementary statement will be required.

An examination of the files of the more important of the horticultural journals of both France and Germany prior to 1880, has been made with the result that references to diseases of cuttings and seedlings are found to be not infrequent, but without exception these contribute nothing, so far as I have been able to find, which will throw light upon the organism concerned. The earliest reference which has been found to be of importance is that of Therry and Thierry ('82). They reported having studied, for more than a year, the mycelial filaments which invaded the cutting-benches of gardeners and florists in the region of Lyons. Although unable to find a spore stage, they described the organism studied as *Mortierella arachnoides* Th. & Th. (araignée des serres), since they considered the vegetative stage to show a close relationship to *M. Ficariae* which they found on leaves of *Ficaria Ranunculoides*. *M. arachnoides* is described as killing the shoots and growing over the fallen tissues, disorganizing them with great rapidity, also growing over the soil in the form of a web of strands. The mycelium is said to be able to grow meters during a single night. The points noted, together with the brief description of the mycelium, strongly sug-

gest *Rhizoctonia*, and it would not be strange that sclerotia were absent under the conditions.

Prompted apparently by the account just referred to, and based somewhat upon that, von Thümen ('82) reports upon the "Vermehrungspilz," and this appears to be the first definite account of the organism from central Europe. His description of the mycelium adds somewhat to that of Therry and Thierry, and like them he found that "* * * die Untersuchungen nichts weiter ergab, als die Anwesenheit zahlreicher, spinnwebendünne, weisslicher oder bräunlicher Mycelfäden, von irgend einer Fructification aber trotz genauesten Suchens auch nicht die mindeste Spur aufzufinden war." Whatever may be the interpretation of these two sets of observations they emphasize (1) the rapidity of growth and violence of the attacks of the organism concerned and (2) the presence of a mycelium as the only stage of the associated organism.

It appears probable that the disease which came to be known as "maladie de la toile" in France is the same as that referred to by Therry and Thierry ('82); nevertheless, such observations as are reported during the next fifteen years leave the question of a causal organism in an unsatisfactory state. Mangin ('94) refers to "la toile" as the disease due to a fungus occurring both in the greenhouse and in the open, producing a decay of leaves and branches, especially at or near the surface of the soil. Recalling what has already been said regarding this fungus it is significant that he remarks: "Quand la *Toile* est bien développée, les filaments mycéliens agglutinent les fragments de terre et deviennent très visibles." Collecting material from the affected area he found that in a few days conidiophores of *Botrytis* appeared on the dead leaves. With cultures of the *Botrytis* he reproduced a disease in lettuce. Since, however, *Botrytis cinerea* might occur upon any debris, and since it also produces a disease of lettuce, it does not follow, of course, that it is the fungus responsible for the troubles here referred to. From the description of the effects, one is inclined to reject the idea that *Botrytis* is concerned in this case. In the same year Prillieux

and Delacroix ('94) found "la toile" abundant in the seed and propagating-beds, market gardens, etc., near Fontainebleau. Affected plants were infested with a sterile mycelium, and they found a fungus, identified as *Botrytis cinerea,* fruiting on the dead material, from which they prepared cultures. No infection experiments were made, and they report no attempt to ascertain if the mycelium in the tissues were really that of *Botrytis.* No additional information is advanced in Mangin's ('94[a]) second paper.

Sorauer ('96) refers to the "Vermehrungsschimmel" of the cutting-benches and of seed-beds as probably belonging to the genus *Sclerotinia.* Reference is made to the spider web-like mycelium, lack of sporophores, and the presence of sclerotia. It is apparently on account of the sclerotia that he refers the fungus to *Sclerotinia.* He indicates that this organism is the chief fungus of the cutting-bench, although *Mucor, Botrytis,* and other organisms may also be found. The description, though far from being complete, is applicable to *Rhizoctonia.*

Aderhold ('97) characterized the fungus and its effects in some detail, and there can be little doubt that he was dealing with the disease then recognized as widely distributed. Moreover, unlike those who preceded him, he obtained the sterile fungus in culture, observed the Monilia-like chains of cells, and also the formation of sclerotia. It seems remarkable that it did not suggest to him Kühn's potato fungus. On the contrary, he agreed with Sorauer in referring the fungus to *Sclerotinia,* without indicating the species.

In a second paper Sorauer ('99) also discusses the fungus more completely. He refers to much of the earlier work, including that of Aderhold. Various stages of the fungus are figured, that is, the mycelium, the moniliform hyphal cells, and the sclerotia, all stages pointing to *Rhizoctonia.* He also refers to a characteristic of his fungus, since frequently observed, doubtless, by all who have studied *Rhizoctonia* in liquid cultures, namely, that of growing up the walls of the vessel above the level of the liquid. He also examined the affected tissues and was able to follow the mycelium in its advance, showing its penetration into the inner bark, like-

wise into the mesophyll of affected leaves. Comment is made on the fact that the death of the cells ensues when very few hyphae have penetrated the tissues.

A review of the earlier work on "la toile" in France is presented by Beauverie ('99) who calls attention to the fact that the fungus producing this disease has been considered by some to be *Botrytis cinerea,* and by others to be *Acrostalagmus albus*, a determination made in one instance at least by Oudemans ('92). This determination was based on material received from the Zoölogical Garden at Rotterdam. Beauverie obtained cultures but fails to describe how the fungus was isolated. From these cultures he was able to obtain only a sterile fungus, which, unfortunately, is not described. Failing to obtain spores he then proceeded with cultures originating from *Botrytis cinerea.* By growing this organism in a moist atmosphere at a temperature of about 33° C. a sterile form was induced. Again, by exposing cultures to a temperature somewhat lower, he affirms that he was able to develop a temporary sterile stage. It would appear that on the basis of these results he draws the conclusion that the first organism isolated represented also a sterile form of the *Botrytis.* He further emphasizes the point that the sterile form is the more dangerous in the production of disease, leading to the inference that conditions resulting in the development of this stage predetermined the prevalence of the malady. It is unsatisfactory to attempt to draw conclusions from this work, but it is at least probable that his first cultures may have been *Rhizoctonia*, and that, however accurately the work with *Botrytis* may have been carried out, it had really no connection with "la toile."

Lindau ('08) follows his discussion of *Rhizoctonia* with a paragraph dealing with the fungus producing disease in the cutting-bench and propagating-houses. The organism is described on the basis of the observations of Sorauer ('99) and Aderhold ('97), reference being made to the characteristic mycelium and chains of short cells, as well as to the occurrence of sclerotia. He questions the relationship with *Monilia*, sug-

gesting that the figures would indicate a closer relationship to *Hormiscium* or *Torula*. Since many of the American studies upon the potato and damping off fungus had previously been examined by him, as the account of *Rhizoctonia* indicates, it is surprising that the possibility of the identity of the "Vermehrungspilz" with *Rhizoctonia* was not suggested.

In his discussion of the fungus Ruhland ('08) considers the earlier work of Aderhold, Beauverie, and Sorauer. Special attention is given to that of Beauverie, and Ruhland takes the view that while in all probability the disease discussed by that investigator is the same as the disease of propagating-beds in Germany, Beauverie's cultures of *Botrytis* were not those of the disease-inducing organism. Ruhland studied the organism in culture, confirms the previous descriptions of mycelium, Monilia-like cells, structure of the sclerotia, etc. He would regard the sclerotia as sclerotial-like bodies (pseudosclerotia), owing to the fact that the structure is homogeneous throughout. Cultures of the fungus here discussed and of *Botrytis cinerea* were studied in parallel series with respect to the capacity to ferment cellulose, and it was found that while this capacity is possessed to a considerable degree by *Botrytis*, as had been previously established, the cellulose-dissolving capacity of the "Vermehrungspilz" is very low. He finds that in the development of the Monilia-like cells there is only a superficial resemblance to *Monilia*, since the spores of the latter are produced basipetally, while those of the seed-bed fungus are formed acropetally. The development of sclerotia from the Monilia-like masses is also noted. Apparently, he concluded that the old cells of the Monilia-like chains, as well as those of the sclerotia, were empty, hence incapable of germination. Earlier studies of *Rhizoctonia* have, however, shown clearly that many old cells of this type are capable of germination, and the peculiarities of this process have been figured and described (Duggar, '99).

In Java a disease of the Cinchona seed-beds was reported by Moens ('82). He describes the damping off of the seedlings as rapidly progressing radially, especially when the conditions are moist. The disease often begins at those points

where the drip from the defective roof falls on the seed-bed. The mycelium is described as spreading rapidly in the form of a web over the diseased plants and adjacent soil. Some observations were made by Stibbe ('06) who also reported that the disease may appear as early as during the first few days of growth. Koorders ('06) observed the disease in a young plantation. An examination of affected stems and roots was made, and a colorless, septate mycelium was found, but there were no evidences of fruiting stages. From these earlier observations of the Cinchona diseases in Java we have only the above evidences of the effect upon the host to suggest *Rhizoctonia* or a related fungus.

The investigations of Rant ('08, '14, '15, '15[a]), previously referred to, are sufficiently complete in all particulars to enable us to identify the fungus as *Rhizoctonia*. To this disease he applies the term "mopo" and "hamamopo" rather than the Dutch "Schimmeldraadjes." He found the effects upon the host to be as previously described, and noted particularly that the cobweb-like growth of the mycelium over the soil and dead plants occurred in a characteristic fashion when the area over the seed-bed was moist. He also emphasizes the point that fragments of soil are firmly held together by the growth of the fungous mycelium. Referring again to the distinctive characteristics of *Rhizoctonia* enumerated earlier, we find that his work covers every point there indicated. The fungus was found to affect not only Cinchona seedlings but was also found in his garden upon the following: *Lychnis diurna*, *Rudbeckia sp.*, *Lobelia erinus*, *Conyza angustifolia*, *Bidens pilosa*, *Antirrhinum majus*, red beet, endive, cabbage, and lettuce. Culturing the fungus upon peptone glucose agar he obtained a good growth with all the characteristics of *Rhizoctonia* which have been referred to in my previous paper. Comparing his measurements with those previously reported, it is found that there is a close agreement throughout. The measurements also agree with those of Aderhold ('97). Rant also instituted a comparison between this fungus and *Botrytis cinerea*, and the results well emphasize the differences between these two organisms. He found likewise that the

"mopo" fungus bears no resemblance to *Acrostalagmus albus*, to which "la toile" in France had been occasionally referred. On the other hand, cultures of the "Vermehrungspilz" obtained from Amsterdam agreed closely with the organism isolated from Cinchona seedlings. Infection experiments with the "mopo" fungus were carried out both on Cinchona seedlings and on seedlings of the plants previously enumerated as affected. In all cases positive results were obtained.

Summary and Discussion.—From the reviews and discussion it seems justifiable to conclude that the common seedbed fungus in Germany and in France is identical with the damping off fungus which has been frequently studied in this country since the investigations of Atkinson ('92). I have given the evidence upon which the conclusion is based that the damping off fungus of the United States is Kühn's *Rhizoctonia Solani* (*Corticium vagum* B. & C.), the cause of important potato diseases and of other types of disease in a variety of host plants. The work of Rant enables us to include in this category of diseases due to *Rhizoctonia Solani* the disease of Cinchona seedlings and of other plants in Java. In establishing these points it is not necessary to consider the earlier and less complete reports upon "la toile" and the "Vermehrungspilz" but particularly the papers of Aderhold ('97), Sorauer ('99), Beauverie ('99), and Ruhland ('08).

Literature Cited

Aderhold, R. ('97). Über den Vermehrungspilz, sein Leben und seine Bekämpfung. Gartenflora **46**:114–126. *f. 1–5.* 1897.

Atkinson, G. F. ('92). Some diseases of cotton. IV. "Sore-shin," "damping off," "seedling rot." Ala. Agr. Exp. Sta., Bul. 41:30–39. *f. 8.* 1892.

Beauverie, J. ('99). Le Botrytis cinerea et la maladie de la toile. Compt. rend. Acad. Paris **128**:846–849, 1251–1253. 1899.

Delacroix, G., et Maublanc, A. ('09). Maladies parasitaires des plantes cultivées. pp. 249–250. 1909.

Duggar, B. M. ('99). Three important fungous diseases of the sugar beet. Cornell Univ. Agr. Exp. Sta., Bul. 163:339–363. *f. 49–63.* 1899.

————, ('15). Rhizoctonia Crocorum (Pers.) DC. and R. Solani Kühn (Corticium vagum B. & C.), with notes on other species. Ann. Mo. Bot. Gard. **2**:403–458. *f. 1–9.* 1915.

Koorders, S. H. ('06). Resultaten van een voorloopig mikroskopisch onderzoek eener wortelziekte van jonge kinaplantjes veroorzaakt door Heterodera-aaltjes en een schimmel. De Cultuurgids. 1906. [Cited from Rant, '15a.]

Lendner, A. ('14). Une maladie de la vigne due à un champignon du genre Hypochnus. Soc. Bot. Genève, Bul. II. 6:104–106. 1914.

Lindau, G. ('08). (In Sorauer's) Handbuch der Pflanzenkrankheiten 2:473–474. 1908.

Mangin, L. ('94). Sur la toile, affection parasitaire de certains végétaux. Bul. Soc. Biol. X. 1:209–210. 1894.

———, ('94a). Sur le parasitisme d'une espèce de Botrytis. Compt. rend. Acad. Paris 118²:882–884. 1894.

Moens, J. C. B. ('82). Die Kinacultuur in Azië 1882. pp. 152–153. 1882.

Oudemans, C. A. J. A. ('92). Contributions à la flore mycologique des Pays-Bas. XIV. Nederl. Kruidk. Arch. II. 6:p. 54. 1892.

Plemper van Balen, B. A. ('00). Het "omvallen" van stekken. Tijdsch. Plantenziekten 6:30–31. 1900.

Prillieux, E., et Delacroix, G. ('94). Maladie de la toile produite par le Botrytis cinerea. Compt. rend. Acad. Paris 118:744–746. 1894.

Rant, A. ('08). De Mopoziekte. Teysmannia 19:433–434. 1908.

———, ('14). Die Ziekten en Schimmels der Kina. Mededeelingen van het Kina Proefstation. 1914. [Cited from Rant, '15a.]

———, ('15). De Mopoziekte. Teysmannia 26:54–57. 1915.

———, ('15a). Über die Mopokrankheit junger Cinchonapflanzen und über den javanischen Vermehrungspilz. Jard. Bot. Buitenzorg, Bul. 18:1–21. *f. 1–8.* 1915.

Ruhland, W. ('08). Beitrag zur Kenntnis des sog. "Vermehrungspilzes." K. biol. Anst. f. Land- u. Forstw., Arb. 6:71–76. *f. 1–3.* 1908.

Sorauer, P. ('96). Über den "Vermehrungsschimmel." Zeitschr. Pflanzenkr. 6:314–315. 1896.

———, ('99). Der Vermehrungspilz. *Ibid.* 9:321–328. *pl. 6.* 1899.

Stibbe, A. F. W. ('06). Eenige aanvullingen op de voordracht van den heer V. W. van Goch, gehouden op het 6de Congres te Malang. De Cultuurgids. 1906. [Cited from Rant, '15a.]

Therry, J., et Thierry ('82). Nouvelles espèces de Mucorinées du genre Mortierella. Rev. Myc. 4:160–162. 1882.

Thümen, F. v. ('82). Der Vermehrungs-Pilz. Wiener Garten Zeit. 7:417–419. 1882.

THE TEXAS ROOT ROT FUNGUS AND ITS CONIDIAL STAGE[1]

B. M. DUGGAR

Physiologist to the Missouri Botanical Garden, in Charge of Graduate Laboratory
Professor of Plant Physiology in the Henry Shaw School of Botany of Washington University

More than twenty-five years ago Pammel ('88, '89) spent two summers in Texas investigating an important cotton disease popularly known as the "cotton blight" or "cotton dying," and as a result of his observations two reports were published upon the cotton root rot,—the latter more appropriate name being applied by him to the disease in question. He determined the causal organism to be a sterile fungus found in some abundance on every dead or dying root, and it was tentatively identified as *Ozonium auricomum* Lk. After a study of Link's type, Shear ('07) described the organism as a new species, *O. omnivorum.*

Since the work of Pammel the disease has doubtless been the object of numerous field observations, more or less extensive, but so far as is personally known to me, and so far as reports are available, the only records are those of Duggar ('09, observations made '01, '02), Shear ('07, observations beginning in '02), Shear and Miles ('07, '07[a]), Heald ('09, '11), and Heald and Wolf ('11, '12). The disease is undoubtedly one of the most destructive of the cotton fungi, and the average losses sustained in the state of Texas have been variously estimated by Orton ('06) and others to be two to three million dollars. In addition, considerable damage is sustained by such crops as alfalfa, beans, sweet potatoes, and certain orchard fruits.

It would appear that the organism is very largely confined to Texas. In that state it seems to have been commonly ob-

[1]The writer was engaged in a study of cotton diseases, especially the Texas root rot, in the Bureau of Plant Industry during the seasons of 1901–02. In the fall of 1902 the work was transferred to Dr. C. L. Shear. Now that the Missouri Botanical Garden is giving special attention to a botanical survey of a certain section of the Southwest, it has seemed appropriate to resume the studies of this fungus so wide-spread and destructive in a large part of that region.

served since 1866. Shear ('07) states that the fungus is distributed from eastern Texas to southern California, and that it has been found in southern Oklahoma and Indian Territory. The writer failed to find the organism in western Louisiana and southwestern Arkansas in 1901, but it was observed in southern Oklahoma in 1915. I am unaware of the data on which the occurrence of the fungus westward to California is reported. Nevertheless, considering the long period of time during which the *Ozonium* has been a serious disease-inducing factor in Texas, it is rather remarkable that it has not been found in Louisiana and Mississippi. In these states the cotton wilt fungus, *Fusarium vasinfectum*, is well known, but the *Ozonium* has never been reported, so far as can be learned. It is almost impossible to assume that the fungus has not been distributed to these states through the various possible commercial channels; so that one is impelled to draw the inference that the establishment of the fungus farther eastward is limited by climatic or soil factors.

It should be recalled that Pammel reported the disease common throughout all sections of Texas in which cotton was grown, with the exception of the gulf prairie region and certain alluvial soils. It seems now certain that there is no soil type in the cotton-producing section of the state which is free from the disease. Nevertheless, the percentage of loss has been invariably greater in the black prairie or black waxy soils, whether with or without outcroppings of rotten limestone. As noted later, the organism occurs on a number of native plants, both trees and herbs, but the observations thus far made give no clue as to whether or not it may be considered endemic. I have been unable to secure data on the occurrence of this fungus from Mexico southward.

From the reports of Pammel, Heald, Heald and Wolf, and from my own observations, the following host plants may be enumerated.

Trees and shrubs: *Ulmus americana, Broussonetia papyrifera, Morus alba, Ficus Carica, Acer saccharinum, Tilia americana, Fraxinus americana, Diospyros Kaki, Melia Azedarach, Pyrus communis, P. Malus, Cydonia vulgaris, Robinia Pseudo-Acacia, Prunus Persica, P. sp.* (cherry), and *Hibiscus syriacus*.

Herbaceous plants: *Beta vulgaris, Chenopodium sp., Cassia Tora, C. marilandica, Medicago sativa, Arachis hypogaea, Phaseolus vulgaris, Vigna sinensis, Linum rigidum, Croton spp., Euphorbia spp.* (three), *Sida spinosa, Hibiscus esculentus, Gossypium herbaceum, Petroselinum hortense, Ipomoea Batatas, Solanum rostratum, Ambrosia psilostachya,* and *Xanthium canadense.*

So far as I am aware, no special attempt has been made to determine all the species of wild herbaceous plants or forest trees affected. The enumeration of hosts given above makes it seem plausible, therefore, that few plants or crops may be free from the disease except the grains and other members of the grass family. At Petty, Texas, in September, 1901, the disease was found upon half a dozen species of weeds in a pasture, the sod of which could not have been disturbed for some years previous.

The chief characteristic of the disease, as far as I have observed it on herbaceous plants, is the sudden wilting and dying of the affected individuals. Occasionally a slight yellowing and unhealthy appearance is found to be due to an infection which does not encircle the main root, and less frequently to the localization of the disease in a few of the larger primary root branches. The first "dying" of cotton is associated with the beginning of blossoming, or of boll formation, commonly from June to July; but Pammel reports one case in which the disease was observed May 6. If the fungus is responsible for injuries in the early stages of growth, then either such injuries have been overlooked or have been ascribed to other causes.

In common with *Rhizoctonia Crocorum* the organism spreads radially, the rate of spread being most variable and, of course, governed by the conditions. The most rapid spread observed by the writer was in a field of irrigated alfalfa. The persistence of the larger "dead spots" season after season in much the same part of the field is accountable in large measure for the popular belief that these are "alkali" spots. The progress of the disease from one year to another is best followed by observing a perennial crop such as alfalfa, in which case new infections are usually relatively few, whereas in a field grown two years or more to cotton

one notes the disappearance of some of the smaller spots of the previous year, and often the number of new infections is considerable.

If diseased cotton stalks are left standing in the field, few or no evidences of the fungus are apparent on the roots the following March. However, some of the more interested growers claim to have observed mats of the fungus turned over by the plow when bedding the land. I have been unable to obtain such material for study. As already indicated, the reappearance of the larger spots, particularly, is a strong indication of the persistence of the mycelium in the soil. This leaves out of consideration the influence of the conidial stage, discussed below, in the persistence of the organism in the same area during successive years.

On lifting wilted stalks of cotton, or stalks recently dead, it is found, from the most favorable material, that the roots are closely invested with a cinnamon-buff[1] felt of hyphae in which strands are conspicuous. The fungus may involve the smallest rootlets, and in addition, the strands of hyphae penetrate the soil and apparently extend considerable distances. The larger soil strands are somewhat darker, often cinnamon-colored. In a badly infected area the strands of hyphae may be found in any lump of soil. Pammel describes the mycelium as brown in color, and Shear as "dirty yellow, whitish when young." In the early stages of development on the host, I find the mycelium pale buff, becoming cinnamon-brown as strands are formed.

In September, 1915, the conditions were particularly favorable at Paris, Texas, for late season infections, so that by examining the roots of many plants taken at the periphery of a diseased area, but themselves apparently healthy, comparatively early stages of infection were observed. In all cases a depression of the bark pointed out the area of penetration of the fungus on the main root. The observations also demonstrated clearly that the attack may be either what I shall designate centripetal or centrifugal. In the former case the infection converges upon the main roots from a few or many small laterals, while in the latter the main root may be com-

[1]Ridgway's 'Color standards and nomenclature' has been employed in the determination of all colors referred to in this paper.

pletely encircled before the fungus extends to the branches. If recovery of affected stalks occurs at all, it is usually by the production of very superficial laterals.

I have not made a careful study of the distribution of hyphae in the various tissues, nor of the mechanism of penetration. From the variety of plants affected it may be inferred that direct infection by the hyphae is general. The presence of lenticels on the enlarged part of the root of cotton by midsummer may possibly be related to the greater susceptibility of this plant, and may also be a factor in determining the frequency of the centrifugal type.

During the seasons of 1901–02 a careful search was made for spore stages of the *Ozonium,* and while several basidiomycetous fungi were found on old cotton stalks in areas where cotton had died from the disease, still no case was observed which, upon careful examination, proved worthy of experimental study. In the examination made of such material special care was given to the characters of the mycelium. However, while examining a semicircular area of dead cotton on the edge of a cotton field in 1902, my attention was caught by a buff-colored circular spot on the ground just outside the cotton field in an area of grass and weeds wherein several of the latter had died from the *Ozonium.* The material observed proved to be an incrustation, or light powdery layer, of spores covering about one square foot in area. One small area of a few square inches only, considerably weathered, was found between the rows of cotton. Removing the soil with some of the spore material and making an examination under the hand lens it was found that strands of the *Ozonium* pervaded the whole mass, and thus there was presented the possibility of a spore form genetically connected with the *Ozonium.* Subsequently, the spore material was studied more carefully. At that time it was clear that strands of the *Ozonium* were present under the masses of spores, but the observations afforded no evidence of the method of spore production. The masses of small spheroidal spores formed a layer sometimes 3 mm. in thickness, and while the broken bits of hyphae observed resembled those of the *Ozonium,* no light was thrown on the relation of spores to mycelium. The conditions so much resembled those under

which oidial formation occurs in cultures of certain *Basidiomycetes* that I subsequently suggested the presence of such an oidial stage of this fungus (Duggar, '09). Owing to the transfer of the cotton disease work to Dr. C. L. Shear at this time the material was laid away, and not again examined until a recent reinvestigation of all material in my hands which might be considered related to *Rhizoctonia*. Then it was ascertained that the best packet of material collected in 1902 had not been studied—that from the area found between the rows of cotton. The reëxamination of this collection resulted

Fig. 1. *Phymatotrichum omnivorum:* types of conidiophores and conidial production.

in finding in some abundance the hyphae which bear the spores. It was furthermore ascertained that the spores were produced at first on the characteristic larger hyphae and on small branches of those hyphae which make up the strands of the fungus in the soil. Typically, the attached conidia were found in heads about short swollen, but not necessarily spherical, branches of the short-celled or strand hyphae. These branches were simple or forked, the forking being at irregular intervals, and occasionally branching was continued from a swollen cell (fig. 1). The spores adhered some-

what, but never in such masses as characterize certain species of *Sporotrichum* or *Verticillium.*

In view of the importance of this observation, and failing to secure material from correspondents, a trip to Paris, Texas, was arranged in September, 1915, with the view of securing fresh material and of making further observations on the fungus in the field. The time selected proved favorable, and an examination of the cotton fields in the vicinity of Paris revealed the *Ozonium* in unusual abundance. Nevertheless, "dead spots" in many fields were examined before the characteristic fruiting stage was found. Then it was located in some quantity in a "dead spot" of about one acre in extent, occurring in a very rich, black waxy soil in a low-lying area of the field. In this area no less than a hundred or more of these conidial circles were found. They varied in diameter from 3 to 30 cm. The majority of these were found in the furrows or "middles" between the rows of cotton, yet they also occurred on the ridge rows, and in seven cases they encircled diseased cotton stalks. In the latter cases, however, the strands penetrating the spore-bearing layer appeared to come from the soil in general rather than directly from the diseased root. In every case the typical color of the spore mass was light pinkish cinnamon, and in thin strata pinkish buff, fading somewhat on drying. At that date the circular area consisted of a more or less perfect crust of spores sometimes broken or powdery. A few of the spore areas had become overgrown with such olive-green moulds as *Cladosporium* and *Macrosporium.*

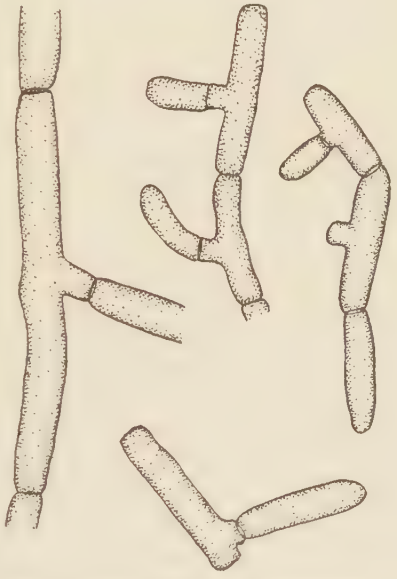


Fig. 2. *Phymatotrichum omnivorum:* large-celled hyphae.

Just below the spore crust, especially towards the center, the typical cinnamon-buff strands of the *Ozonium* occurred in abundance. A similar type of mycelium also permeated the soil to a considerable extent in the immediate vicinity and often about the periphery of the spore-bearing area.

The study of the collections made in 1915 emphasize the diversity in the form of hyphae as well as in the method of spore production. Although no circular areas were found in an early stage of development, yet some of the older ones yielded on the periphery material from which the method of spore formation could be followed. It would appear that a superficial growth of large, branched, almost hyaline hyphae is first formed (fig. 2), covering the surface with a delicate stratum. These hyphae are sometimes Rhizoctonia-like. They may also bear conidiophores at irregular intervals, the latter arising usually as short assurgent branches. These branches either produce conidia directly, or commonly after becoming variously forked (fig. 1). As further growth proceeds, however, definite strands are developed, and then swollen branches from any cell of the strand may produce spores. Later the wave of spore production appears to involve practically the whole mycelium, and the conidia are found laterally distributed in various positions on the surfaces of both the strand and simple hyphae, so that in the end there is practically nothing left but a pulverulent mass consisting of the conidia and remains of the mycelium and strands. The conidia are sessile, but occasionally cells bearing conidia exhibit a somewhat roughened surface. The true character of the fungus cannot be determined unless one is careful to secure the youngest material available, that is, from near the margin of the spore area, or otherwise a spore forming area in an early stage of development.

The diverse characteristics of the mycelium, as found on the surface of the host and in the soil, may be briefly summarized as follows:

(1) Large-celled type. Hyphae Rhizoctonia-like, often abundant on the margins of the conidial areas, measuring frequently 20μ in diameter, with cross walls 60–120μ apart. This type should also include some of the arachnoid mycelium

on the surface of the roots, also those representing early stages of strand formation (fig. 2).

(2) Strand hyphae. In these the individuality of the hyphae is practically lost, the strands being ultimately plectenchymatic bands in which the individual cells vary considerably in diameter, the larger cells of young strands resembling somewhat the larger hyphae above mentioned. It is interesting to observe that they may serve not only to spread the fungus vegetatively, but superficial soil strands may function as a conidial stroma. They are also more or less sclerotial and are doubtless an important factor in the persistence of the fungus in the soil (fig. 3).

(3) Acicular type. The arachnoid mycelium with which the root is invested gives rise to certain fairly rigid hyphae

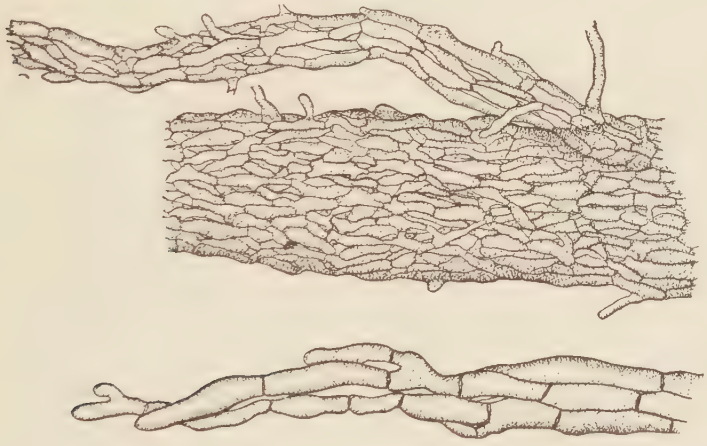


Fig. 3. *Phymatotrichum omnivorum:* mycelial strands; upper, old strand from root of cotton; lower, young strand from conidial area.

which in turn produce branches that are most frequently in pairs, that is, opposite, and at right angles. Branching is also not infrequently verticillate. In all cases such branches are characteristic in appearance, being rigid and needle-like, tapering to very fine filaments (fig. 4). This type has been found only on the roots.

It is necessary to add, however, that intermediate types between the various forms mentioned occur. In general, the

mycelium is Rhizoctonia-like rather than Ozonium-like, yet no sclerotia have been found. In this connection I may add that it is proposed in a later paper to bring together certain observations which have been accumulating on Ozonium stages of *Basidiomycetes.*

Numerous germination cultures have been made with material from two weeks to three months old. While this has afforded some interesting suggestions, germination in any particular medium has been, on the whole, erratic. The data are

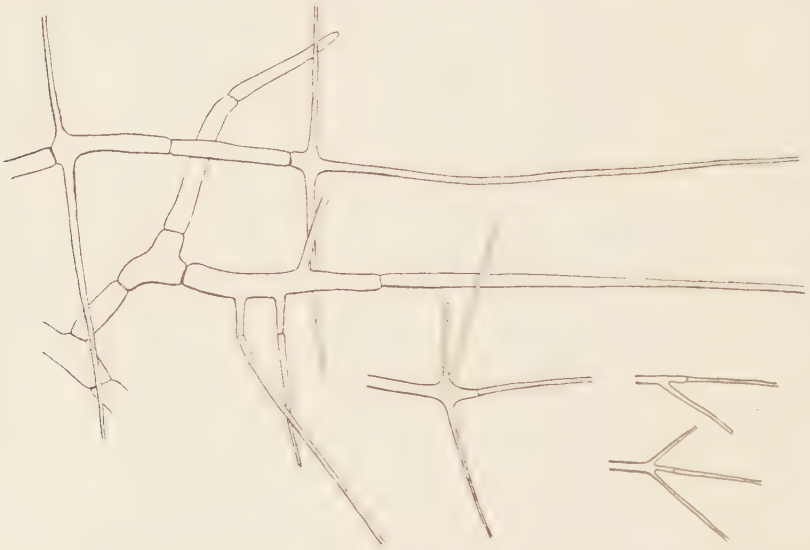


Fig. 4. *Phymatotrichum omnivorum:* acicular hyphae exhibiting characteristic modes of branching.

reserved for a later report. The cultures which have been prepared from the newly infected root, as also those from erratic spore germination, have yielded a sterile mycelium which, while in itself distinctive, resembles only in a general way the mycelium found on the roots and in the soil. The mycelium in culture is hyaline, forming on young bean stems and on various other culture media a dense, slow-growing mat, seldom rising more than 3 mm. above the substratum, and never becoming fluffy in appearance. After standing for some weeks this mycelium becomes somewhat colored, assuming a warm buff to light ochraceous buff. In culture the

hyphae are likewise most diverse in diameter, varying from those 15–20μ to others extremely delicate and flexuous (fig. 5). No truly acicular branches, however, are produced under ordinary cultural conditions. With age, the mycelium somewhat collapses toward the substratum and has a greater tendency to grow along the glass tube in the form of false strands. Grown in soil, by covering a vigorous growth on bean stems with a layer of loam, hyphae similar to those just described are produced; but, in addition, there are formed here and there vesicular enlargements, and the latter are sometimes

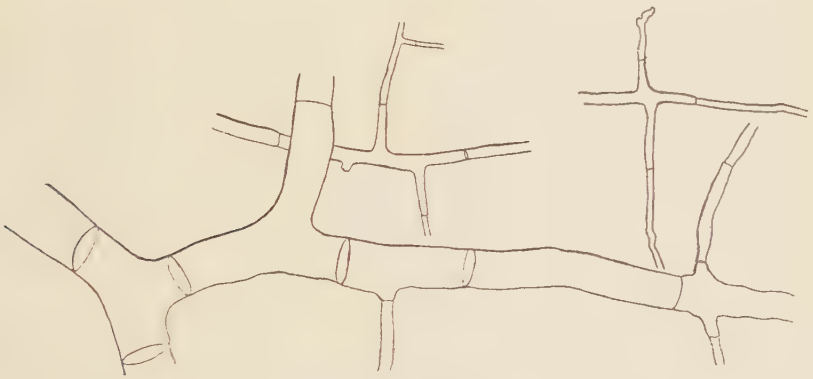


Fig. 5. *Phymatotrichum omnivorum:* hyphae grown on bean stems, from a culture 60 days old.

in clusters, the branches becoming two to three times forked. The conditions for conidial formation have not been determined.

It will be seen that the connection of the conidial stage with the *Ozonium* rests at present upon two classes of observation: (1) the presence in the conidial layer of hyphae and strands (bearing conidia) found to be identical with the characteristic mycelium on the roots of affected plants, and (2) the identity in artificial culture of the mycelium originating, on the one hand, from diseased roots, and, on the other, from the germination of the conidia. To complete the proof it would, of course, be necessary to secure positive results by inoculation with conidia, or better, positive results with a pure culture originating from conidia. Unfortunately this phase of the work has not been successfully developed. In

this connection it should be said that no inoculations carried out in the greenhouse up to the present have given positive results. As a source of infection I have employed (1) diseased cotton roots fresh from the field (showing the *Ozonium* in abundance), (2) fresh conidia, and (3) cultures from diseased roots. It is apparent that the conditions for infection have not been made satisfactory. Such experiments are to be continued both in the greenhouse and in the field.

It has been found difficult to place the fungus satisfactorily in any established genus of the *Hyphomycetes*. While in the manner of conidial production it is undoubtedly related to such genera as *Phymatotrichum*, *Botryosporium*, *Rhinotrichum*, etc., it does not exhibit all the characteristics of any of these genera. Nevertheless, it has seemed best, after examining all available exsiccati material of forms which might be related, to place the fungus tentatively in the genus *Phymatotrichum*, and, if Bonorden's figure (Handb. d. allgem. Myk. *pl. 8, f. 181*) is correct, fairly close to *P. pyramidale* Bon.[1] The fungus is clearly excluded from *Botryosporium*, the conidiophores of which are erect, with conidia produced on sterigmata. Slightly emended, the genus *Phymatotrichum* would be of taxonomic convenience. In placing the Texas cotton fungus in this genus, I would not convey the impression that this fungus is considered to belong to the *Ascomycetes*. Accepting Shear's specific name, a revised description of the organism is appended.

Phymatotrichum omnivorum (Shear) Duggar, n. comb.

Hyphae diverse, forming on the host (1) a loose weft of large, branched cells, producing more rigid hyphae with acic-

[1]It should be noted that the genus *Phymatotrichum* Bonorden (Handb. d. allgem. Myk. p. 116. *pl. 8, f. 181.* 1851) was at first reduced to a section of *Botrytis* by Saccardo (Sylloge 4:134. 1886). Later, however, he restored it to generic rank (Sylloge 16:1033. 1902) to accommodate a species of Oudemans. Costantin (Les Mucédinées simples, pp. 44–46. *f. 12.* 1888) gives a detailed description of a fungus, which was obviously considered *Phymatotrichum pyramidale* Bon., under the name *Botryosporium pyramidale* Cost. There can be little doubt that the fungus figured by Costantin is properly placed. However, the source of Costantin's material was apparently not the original specimen of Bonorden, and since his figure differed in many respects from that of Bonorden, it is perhaps fair to question the identity of the two fungi. Lindau (Rabenhorst's Kryptogamenflora 1 (Abt. 8):117. 1904) seems to accept the views of Costantin. He also cites as exsiccati, Vestergren, Mier. rav. sel. 421.

ular branches, these last often arising at right angles and opposite, and (2) plectenchymatic strands; almost hyaline when young to cinnamon-brown in mature strands. Fertile hyphae arising irregularly from the large-celled mycelium or direct from cells of the strands, assurgent, simple or forked, with spore-bearing portion vesicular (spheroidal to ellipsoidal), often 20–28μ in length and 15–20μ in diameter. Spores finally arising also from undifferentiated hyphal and strand cells, hyaline, spheroidal to ovoidal, the spheroidal averaging 4.8–5.5μ in diameter, the ovoidal measuring 5–6$\times$6–8μ; extreme diameters, 3.2 and 9.8 μ. The conidial stage forms a continuous pulverulent, sometimes crust-like, area on the soil.

Hab. Hyphae on living roots of many plants and in soil, conidial stage on soil in the vicinity of diseased plants.

Specimens have been deposited in the herbaria of the Missouri Botanical Garden and the Bureau of Plant Industry, Washington, and in the collection of Professor W. G. Farlow, Cambridge.

Bibliography

Atkinson, G. F. ('93). Method for obtaining pure cultures of Pammel's fungus of Texas root rot of cotton. Bot. Gaz. **18**:16–19. 1893.

Curtis, G. W. ('92). Alfalfa root rot. Tex. Agr. Exp. Sta., Bul. 22:209–215. 1892.

Duggar, B. M. ('09). Fungous diseases of plants. pp. 479–481. *f. 240.* 1909.

Heald, F. D. ('09). Symptoms of disease in plants. Univ. Tex. Bul. 135:pp. 57–58. *f. 56.* 1909.

————, ('11). Texas root rot of cotton. Tex. Dept. Agr., Bul. 22:303–308. 1911.

————, and Wolf, F. A. ('11). List of parasitic bacteria and fungi occurring in Texas. Tex. Acad. Sci., Trans. **11**:10–44. 1911.

————, ————, ('12). A plant disease survey in the vicinity of San Antonio, Texas. U. S. Dept. Agr., Bur. Pl. Ind., Bul. 226:pp. 26, 38, 41, 48, 49, 55, 57, 59, 80. *pl. 11, f. 3.* 1912.

Orton, W. A. ('02–'07). Plant diseases in the United States. U. S. Dept. Agr., Yearbook **1902**:718; **1903**:555; **1905**:603, 604, 610; **1906**:506; **1907**:586.

Pammel, L. H. ('88). Root rot of cotton, or "cotton blight." Tex. Agr. Exp. Sta., Rept. **1**:50–65. 1888; *Ibid.*, Bul. 4:18–33. 1888.

————, ('89). Cottonroot-rot. *Ibid.*, Rept. 2:61–86. *pl. 1–5.* 1889; *Ibid.*, Bul. 7:1–30. *pl. 1–5.* 1889.

Shear, C. L. ('07). New species of fungi. Bul. Torr. Bot. Club 34:pp. 305–306. 1907.

————, and Miles, G. F. ('07). The control of Texas root-rot of cotton. U. S. Dept. Agr., Bur. Pl. Ind., Bul. 102:39–42. *f. 3.* 1907.

————, ————, ('07a). Texas root-rot of cotton. *Ibid.*, Circ. 9:1–7. *f. 1* 1907.

CABBAGE YELLOWS AND THE RELATION OF TEMPERATURE TO ITS OCCURRENCE

JOSEPH C. GILMAN
Formerly Rufus J. Lackland Fellow in the Henry Shaw School of Botany of Washington University

Introduction

In recent years the diseases of plants caused by fungi belonging to the genus *Fusarium* have assumed greater and greater importance from an economic standpoint. A large amount of work has been done on the descriptions of such diseases on new hosts, and on the taxonomy of the genus *Fusarium*, but there has been comparatively little study of the relations of these fungi to their hosts, especially of the conditions under which members of this genus may become harmful parasites. Therefore, any work which throws light on this point is of value scientifically, first, because the mode of attack and the other relations of the parasitic species of *Fusarium* are all very closely related and very similar in their nature, and second, because of the possibility of throwing light on the problem of immunity or resistance of plants to the attack of parasitic organisms. The latter point is of particular interest, since it will be recalled that, up to the present time, practically the only control of the diseases caused by fungi belonging to this genus, has been by the selection or development of strains of the host resistant to fungous attack.

While assisting in the work of the development of strains of cabbage resistant to yellows in Wisconsin, investigations were undertaken to find the cause of the disease and the relations between host and parasite. During these investigations the relation of temperature to the occurrence of this disease was found to be of utmost importance, and the principal part of the work was accordingly devoted to this side of the problem. Nevertheless, before taking up these observations and experiments in detail, the results of the investigations into the etiology and pathological anatomy of the disease should

be discussed, in order that the physiological relations between host and parasite may be understood more clearly. A brief resumé of the literature on cabbage yellows will show the state of our knowledge of this disease at the time these investigations were taken up.

History of the Disease

The disease was first reported by Smith ('99, '99[a]), as occurring in New York State in 1895. He found the trouble exceedingly severe, threatening "to put an end to the successful growing of cabbages in considerable districts." He considered that the disease was "due to a soil Fusarium" but made no inoculation experiments. Aside from this observation his only contribution to our knowledge of the disease was in relation to its persistence in the soil; the organism resisted drying in the laboratory for three and one-half years. Woods ('99) showed that the characteristic symptom, the yellowing, was due to the presence of an increased amount of an oxidizing enzyme, peroxidase, in the diseased leaf tissue. Norton and Symons ('07) reported the presence of the disease in Maryland, but performed no experimental work.

Harter ('09), of the Bureau of Plant Industry, made inoculations of sterile soil with pure cultures of a *Fusarium* isolated from the stems of diseased cabbage plants. He was able to produce the characteristic symptoms in plants grown in that soil. In one trial, 83 per cent of these inoculations were successful; in a second, he reported that a large percentage of the plants showed typical symptoms, but no exact figure was given. He also made the statement that the fungus was a vascular parasite and formed microconidia in the vessels of the living plant. In addition to this paper Harter ('12) has published merely a popular account of the disease. Manns ('11) reported the disease as prevalent and destructive in Ohio but limited his work to field observations of a general nature.

Jones ('13, '14, '14[a]) in a series of papers reported the development of strains of winter and "kraut" types of cabbage which are highly resistant to the attack of this disease. These strains were developed by means of selection of sound

plants from badly diseased fields. In his last paper he reported that in the resistant strain 100 per cent formed commercial heads, or a yield of 18.8 tons to the acre; on the other hand, in the commercial strain used as controls, only 46 per cent of the plants lived and 24.2 per cent headed, or a yield of 2 tons to the acre.

These results show that, as far as practice is concerned, the disease has been controlled, but much remains to be done on the other aspects of the problem of the relation of host and parasite. Before discussing these phases, however, a brief description of the disease will not be out of place.

Symptoms of the Disease

The first evidence of the disease in the greenhouse is found on very young seedlings, often just after the appearance of the first true leaf, and is characterized by a rapid wilting of the cotyledons and dying of the roots while the stem is still turgid and, to all external appearances, normal. If, however, the conditions are not favorable for the attack of the fungus so early in the life of the host, the characteristic symptom —the yellowing of the leaf, to which the disease owes the name of "yellows"—is found. This yellowing may invade the entire plant, in which case wilting and death rapidly follow, or it may be confined to merely one side of the plant or leaf. If this one-sided invasion occurs, the plant or leaf ceases growth on the diseased side, but the green portions continue their development, bringing about a curvature of the plant or leaf toward the diseased area. This type is most frequently found on plants grown in the seed-beds in infected soil. These one-sided plants are usually stunted with the leaves loosely attached to the stem, so that they fall at the touch. If transplanted into the field such plants may die immediately, or if conditions are favorable for their development, they may live all summer, becoming stunted individuals with the lower leaves dying and dropping off, leaving a tuft of living leaves at the tip of a bare stalk. When healthy seedlings are transplanted to diseased soil the same characteristics occur; some plants die immediately—first, however, losing their chlo-

rophyll—while others become one-sided and stunted, but live throughout the summer. The latter rarely form heads.

Causal Organism

Taxonomy

Cabbage yellows is caused by a soil fungus belonging to the genus *Fusarium*. The organism was first described by Wollenweber ('13) who, basing his classification on the work of Appel and Wollenweber ('10), placed it in the section *Elegans* and named it *Fusarium conglutinans* Wollenw. The description given by this author is as follows:

> '*Fusarium conglutinans* n. sp. differs from *F. orthoceras* * * * * * in the absence of a wine-red color on rice which is a striking character of typical species of the section Elegans. * * * * Vascular parasite, cause of wilt disease of *Brassica oleracea* var. *capitata* (proved by Erwin F. Smith, L. R. Jones, L. L. Harter) in the United States of America.'

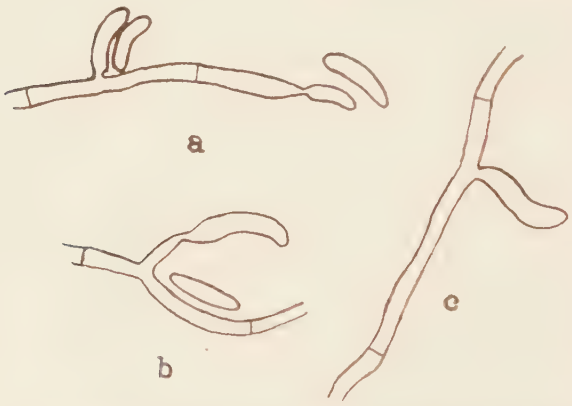


Fig. 1. Conidia production of *F. conglutinans* in Uschinsky's fluid after 48 hours: *a*, Culture V; *b*, Culture II; *c*, Culture I. Camera lucida sketch × 1000.

This description was based on a culture from the Laboratory of Plant Pathology of the University of Wisconsin. The same year Stevens ('13) ascribed the yellows to *Fusarium Brassicae* Thüm., citing Harter ('09) as his authority in spite of the following facts: first, that Harter specifically stated that he was working with an undescribed species and, second, that Wollenweber had included Harter's organism in his new species, *F. conglutinans*. Moreover, the organism that is parasitic on cabbage in the United States differs from *Fusarium Brassicae* Thüm. as described by De Thümen ('80)

in the following respects: *Fusarium Brassicae* forms *sporodochia,* while in *F. conglutinans* these are much reduced and usually not formed at all. *F. Brassicae* has conidia which are two-septate, while *F. conglutinans* has conidia, the majority of which are non-septate with a few one- and three-septate forms, two-septate spores not appearing. The main point of resemblance, from the description of *F. Brassicae,* is that the spore measurements fall within the same limits—a fact which, in view of the above differences, would scarcely suffice to put the two as synonymous.

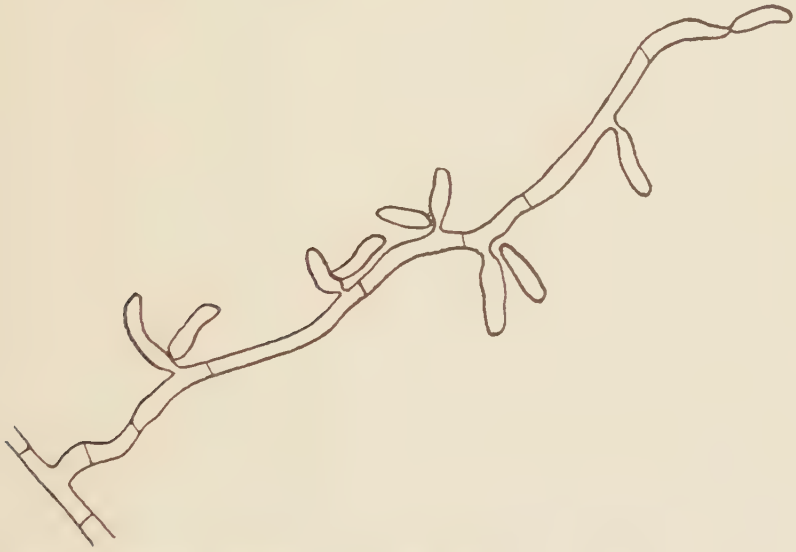


Fig. 2. Conidia production of *F. conglutinans* in Uschinsky's fluid after 48 hours. Culture I. Camera lucida sketch × 1000.

While the above description by Wollenweber is perhaps sufficient to differentiate *F. conglutinans* as a distinct form, it is hardly adequate as a diagnosis of the species; moreover, the question may be raised as to whether a physiological character, such as color production on a special medium, which has not been regarded as of specific rank in related genera, is sufficient basis for the establishment of a new species in the genus *Fusarium.* This, of course, introduces a new factor into the taxonomy of this genus, but the writer would hold it

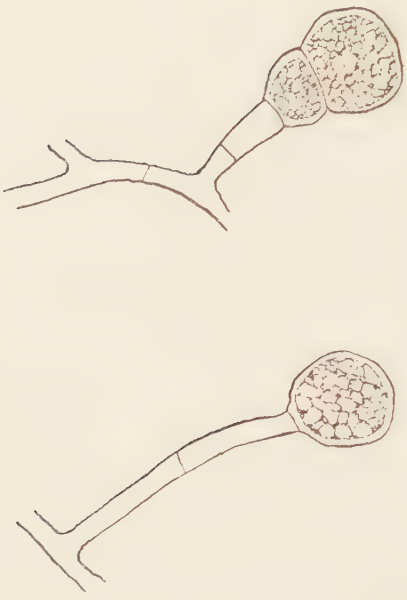


Fig. 3. Production of chlamydospores of *F. conglutinans* in Uschinsky's fluid after five days. Culture XI. Camera lucida sketch × 1000.

to be justifiable in such a group as the genus *Fusarium*, where a classification based on morphology alone has led and would continue to lead to confusion in many cases. That this character is constant in the case of *F. conglutinans*, there can be no doubt, but as additional evidence, some forty-three cultures of this organism have been maintained in the laboratory in connection with this work for a period of from six months to two years, and in no case did they produce red color on rice media, while cultures of *F. orthoceras*, carried as controls, did.

Moreover, on other media the organism maintained constant similarities with cultures from similar sources which on inoculation into the host produced the disease. The organisms were grown on potato hard agar, dextrose bouillon agar, soil extract agar, cooked potato plugs, cooked potato stems, and cooked rice. The mycelium in all cases grew well, giving a white fluffy growth at first, which gradually turned cream color, and in old cultures showed ochreous to brown strands in the aërial mycelium in the upper part of the tube. Spores of the "micro" type were found in all cultures in great abundance, especially during the early part of the growth of the cultures. The production of aërial mycelium was most abundant in those cases where the amount of carbohydrate in the substratum was greatest or most available.

Fig. 4. Method of branching of mycelium of *F. conglutinans* in Uschinsky's fluid. Culture I. Camera lucida sketch × 1000..

After growth of a few weeks chlamydospores were found in most of the cultures, the microspores were beginning to become abnormal, and the few macrospores were also breaking down. The macrospores were found to be produced best on potato stems, next best on the potato agar, while very few appeared on cooked potato plugs and cooked rice.

Besides the tube cultures, hanging-drop cultures in a modified Uschinsky's fluid[1] were observed. In this medium the fungus produced microspores abundantly in cultures only two days old when kept at room temperatures. Chlamydospores were found to begin to form in cultures but five days old, although they did not mature in so short a time. Usually the first chlamydospores occurred terminally; later other parts of the mycelium rounded up to form the intercalary spores.

Fig. 5. Conidia of *F. conglutinans*. Culture LVI on potato stem. Camera lucida sketch × 800.

A revised description of the fungus is as follows:

Fusarium conglutinans Wollenw.

Sporodochia lacking or greatly reduced; pionnotes never present. Conidia borne on short conidiophores strewn throughout the mycelium, majority non-septate, a few one-septate and three-septate. The non-septate conidia ovoid to ellipsoidal, hyaline, 2.5–4 × 6–15μ, the majority being 2.5–3 × 7–10μ. One-septate conidia hyaline, cylindrical, with

[1] This medium was a modification of the standard Uschinsky's fluid, and was made up as follows:

Water, distilled	1000 grams	Magnesium sulphate	0.3 grams
Glycerin	30 grams	Dipotassium phosphate ..	2 grams
Sodium chloride	5 grams	Ammonium tartrate	6 grams
Calcium chloride	0.1 grams	Sodium asparaginate	3 grams

The solution was sterilized at ten pounds pressure for twenty minutes in the autoclave.

rounded ends, long axis slightly bent, dimensions $4 \times 19\mu$. Three-septate conidia fusiform, hyaline, with both end-cells tapering and with rounded tips, no sharply differentiated foot, dimensions $3.5–5.5 \times 25–33\mu$. Conidia with higher septation very rare.

In culture aërial mycelium white at first, becoming cream-colored and finally showing a development of ochreous strands of thallo-plectenchymatic tissue throughout, but no sclerotia. Grows well on potato agar, dextrose bouillon agar, Uschinsky's fluid, cooked rice, cooked potato plugs, and potato stems. On no medium is there any color production except the slight yellowing spoken of above. In older cultures terminal or intercalary chlamydospores are produced. They are usually one-, sometimes two-celled, spherical to ovoid with a thick irregular wall, frequently slightly colored. Dimensions $7–12 \times 7–15\mu$.

The fungus is found in the soil and is a vascular parasite attacking cabbage, *Brassica oleracea* var. *capitata*, causing the yellows, or wilt disease. It has also been isolated as a saprophyte from China aster and tubers of potato (Lewis, '13).[1]

TEMPERATURE STUDIES

In view of the later work in regard to the relation of temperature to the occurrence of the disease, it will be well to discuss briefly this relation for the fungus in pure culture, both as to growth and germination of conidia. The latter will be considered first.

In order to obtain spores of the fungus free from pieces of mycelium, a bit of mycelium was placed in a hanging-drop of Uschinsky's fluid in a Van Tieghem cell which was partially filled with Uschinsky's fluid below. The spores were formed abundantly at room temperatures in forty-eight hours and allowed to drop into the lower liquid from which they were

[1] Through the kindness of Dr. W. J. Morse, of the Maine Agricultural Experiment Station, transfers of these two strains of *Fusarium conglutinans* were obtained, and inoculations made on February 2, 1915, on five plants each, and again on February 26, 1915, with the strain from aster on ten plants; both gave negative results. This would indicate that they belonged to a saprophytic strain, although the results might be due to the fact that the fungi had been so long in culture that they had lost their virulence, or to the small number of trials made. Control cultures of this fungus from cabbage, however, gave 80 per cent infection in the first case and 100 per cent in the second trial.

transferred to other Van Tieghem cells by means of a sterile pipette. They were immediately placed in the incubators at the desired temperatures, and observed at intervals for germination. All observations were made in duplicate, and the trials were repeated twice to verify them. The temperatures used were 8–10°C., 10–12°C., 16°C., 21°C., and 33°C. The results are brought together in table I.

TABLE I

GERMINATION OF CONIDIA OF FUSARIUM CONGLUTINANS AT VARIOUS TEMPERATURES

Hours of exposure	Germination (+) at the following temperatures									
	8–10° C.		10–12° C.		16° C.		21° C.		33° C.	
	Trial no.		Trial no.		Trial no.		Trial no.		Trial no.	
	1	2	1	2	1	2	1	2	1	2
1	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	+	+
6	—	—	—	—	—	—	—	—	+	+
8	—	—	—	—	+*	+*	+	+	+	+
12	—	—	—	—	+	+	+	+	+	+
24	—	—	—	—	+	+	+	+	+	+
36	—	—	—†	—†	+	+	+	+	+	+
72	—	—	—	—	+	+	+	+	+	+

* In a later test in which more frequent observations were made, conidia at this temperature (16°C.) germinated 12 hours after the beginning of the exposure.

† At this temperature (10–12° C.) spores were found to germinate after 36 hours in a later experiment. The number that germinated, however, was very small and the growth exceedingly slow.

It will be noted that, as was to be expected, spores of the fungus germinated best at the higher temperatures of the experiment, although they were able to grow slowly at the lower temperatures. These facts are further borne out by the growth of the fungus on potato agar. Transfers of a bit of the mycelium from a rapidly growing culture were placed in the center of plates of potato hard agar, and the plates were then placed in the incubators at the desired temperatures.

Three plates were carried at each temperature, and measurements of the growth of the colonies of the mycelium were made each day for ten days, after which time the experiment was discontinued because of the contamination of some of the plates and the drying out of others. The results are given in table II.

TABLE II

GROWTH OF FUSARIUM CONGLUTINANS AT VARIOUS TEMPERATURES

Age of colony in days	Diameter of colony in cm. at various temperatures											
	4–8° C.			18° C.			21–22° C.			25° C.		
	Plate no.			Plate no.			Plate no.			Plate no.		
	1	2	3	1	2	3	1	2	3	1	2	3
1	....	....	....	....	....	....	0.9	0.9	0.6	0.7	1.1	0.1
2	....	....	....	0.1	0.1	0.1	1.6	1.5	1.2	1.8	2.0	1.1
3	0.1	0.1	0.1	0.6	0.6	0.6	2.0	2.0	1.8	2.0	2.2	1.7
4	0.2	0.2	0.1	1.0	0.9	0.9	3.0	2.8	2.4	2.9	3.2	2.9
5	0.4	0.5	0.4	1.2	1.1	1.2	3.6	3.4	3.0	3.4	—*	3.1
6	0.5	0.7	0.5	1.4	1.2	1.3	4.0	3.8	3.4	3.8	....	3.7
7	0.7	0.8	0.9	1.5	1.3	1.5	4.5	4.3	—*	4.6	....	4.4
8	1.1	1.1	1.1	1.9	1.7	1.7	5.1	4.9	....	5.1	....	5.3
9	1.4	1.5	1.3	2.0	1.8	1.8	5.5	5.4	....	5.6	....	6.0
10	1.6	1.7	1.4	2.2	2.2	1.9	6.2	6.0	....	—*	....	6.6
Average growth per day	0.16	0.17	0.14	0.22	0.22	0.19	0.62	0.60	0.56	0.62	0.80	0.66
Average for each series	0.16			0.21			0.59			0.69		

*Contaminated.

If the growth of *Fusarium conglutinans* be compared with that of some of our more common saprophytic forms as, for example, *Penicillium glaucum*, or *Aspergillus niger*, as reported in the literature, it will be noted that, while the optimum of these forms is also high, they can grow better than *F. conglutinans* at the lower temperatures. In other respects the curves of growth of these forms would approximate one another very closely.

No attempt was made to find the maximum and minimum growth temperature for this fungus, because the object of the work was to find, if possible, an explanation for the fact that yellows occurred in the host at high temperatures rather than at low. This relation will be discussed later when a full review of the points involved will be taken up.

Inoculation Experiments

The first inoculation experiments were tried during the summer of 1912. On July 17 five flats of soil were planted to cabbage; three contained soil brought from the experimental plot at Racine and two, normal greenhouse soil. One of the latter was left as a control, and the other was inoculated with spores from a pure culture of the fungus. These flats were kept shaded on the north side of some shrubbery in the pathological garden and no typical yellows had appeared by September 7, when they were discarded. On August 23 five plants in the pathological garden were inoculated by placing mycelium of a rapidly growing culture in contact with the roots. No disease was found up to October 22, when frost killed the plants. The seedlings were two weeks old at the time of inoculation. Again, on September 10, thirty healthy plants were transferred to three flats of soil brought from the experimental plots at Racine, but no disease was found in any of the flats by December 2.

On January 6, 1913, twelve pots of sterile soil were planted to cabbage and inoculated by stirring cultures of *Fusarium* into the pots. Twelve pots of diseased soil from the experimental plot, eight of sterilized soil, and four of normal undiseased soil were planted as controls. Spores were abundant in all the cultures used. No yellows had appeared by April 29, and the plants were then pulled and the pots replanted. Instead of keeping this second lot in the open greenhouse,

however, they were placed under a glass, such as is used in a forcing-bed, thereby giving a higher temperature than could be attained in the open house. On January 14 the plants in one pot of inoculated soil showed the characteristic symptoms, and on July 10 the plants in a second pot had succumbed. On July 12 a third pot contained plants showing the disease. Damping off due to *Rhizoctonia* interfered with the value of this trial. The diseased plants were plated out on potato hard agar in all cases, and the typical *Fusarium* found to be present. As will be noted, it was only after the temperature of the pots had been raised that there was any occurrence of the disease. Curves showing the temperature attained by placing the plants under the glass are given in fig. 6.

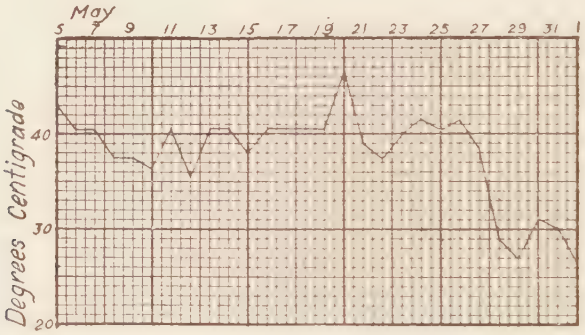


Fig. 6. Diagram showing temperature under glass in greenhouse during inoculation experiments, May 5–31, 1914.

On May 10, 1913, another inoculation experiment was started with seedlings grown in normal greenhouse soil. The plants used were about ten days old — just showing the first true leaf. Five pots of soil were used, five seedlings in each pot. Pot 1 was left as a control, while the roots of the plants in the other pots were dipped into a suspension of spores from a pure culture and immediately planted. On May 13 they had all recovered from the effects of transplanting and were in good

condition. On July 10 symptoms of yellows showed in pots 4 and 5; on July 14 the plants in pot 3 became diseased, but no disease was found in pots 1 or 2. The plants were plated on potato hard agar, and *F. conglutinans* was recovered from plants from pots 3, 4, and 5. None was found on seedlings plated from pots 1 and 2. Culture V, which upon reinoculation again produced the disease, was one of these cultures (table v).

On May 27, 1913, a more extensive inoculation experiment was started; part of the pots containing the plants were placed in the greenhouse and part in the pathological garden. As the greenhouse was not heated, the difference of conditions was not noticeable, and, therefore, the results are combined. For this trial twenty pots were planted to cabbage. These pots were in duplicate, ten being placed in the greenhouse and ten in the soil of the garden. The treatment of the soil in these pots was as follows: Eight pots contained soil from the experimental plots at Racine, and eight others normal greenhouse soil. These sixteen containers were sterilized in an autoclave at eleven pounds pressure for four hours. Four of each of them were used as controls, four were inoculated with pure cultures of *F. conglutinans,* and the remaining four were inoculated with wilted leaves of the diseased plants. Two pots of normal greenhouse soil and two of normal diseased soil were added to the series as controls. The cultures were added by mixing them with the surface soil in the pots. The seed used were not good, and, therefore, the plants did not come up well, so that in the following pots there were no plants: one pot of diseased soil sterilized but not inoculated; two pots of diseased soil sterilized and inoculated with pure cultures; two of diseased soil sterilized and inoculated with the leaves; one pot of normal greenhouse soil not inoculated; and one of sterilized greenhouse soil inoculated with leaves. The results of this experiment are given in table III.

TABLE III

RESULTS OF INOCULATIONS WITH PURE CULTURES OF FUSARIUM CONGLUTINANS

Pot no.	Kind of soil	Treatment of soil	Plants per pot		
			Total no.	No. diseased	Percentage diseased
1	Infected	Sterilized	7	0	0
2	Infected	Sterilized	0		
3	Infected	Ster'z'd and inoc'l'd	4	3	75
4	Infected	Ster'z'd and inoc'l'd	1	1	100
5	Infected	Normal	5	4	80
6	Infected	Normal	6	6	100
7	Uninfected	Normal	1	0	0
8	Uninfected	Normal	0		
9	Uninfected	Ster'z'd and inoc'l'd	3	1	33
10	Uninfected	Ster'z'd and inoc'l'd	5	5	100
11	Uninfected	Ster'z'd and inoc'l'd	1	1	100
12	Uninfected	Ster'z'd and inoc'l'd	2	1	50
13	Uninfected	Sterilized	6	0	0
14	Uninfected	Sterilized	4	0	0
15	Uninfected	Ster'z'd and infect. leaves	2	1	50
16	Uninfected	Ster'z'd and infect. leaves	0		

The results are not as conclusive as they might be, however, as the number of plants used was very small due to the poor seed mentioned above. The pots in which no plants grew in either of the duplicates were omitted. An idea of the appearance of the plants at the time of making counts may be had from pl. 1, fig. 2. It should be noted that these successful inoculations were made at the warmest time in the summer. Plates were made on July 14 from plants in each pot, and in all cases the diseased seedlings gave pure cultures of *F. conglutinans*, while those from the controls remained sterile. Culture X was one of these and upon reinoculation again produced the disease (table v).

On June 12 the above experiment was repeated, using three flats of soil (from the experimental field), two of which had been sterilized at eleven pounds pressure for four hours on two successive days, the other remaining untreated. One of

the sterile flats was inoculated by stirring into its surface ten pure cultures of *F. conglutinans* which were sporulating abundantly. Then all the flats were planted. As an additional control, a flat of normal greenhouse soil was placed in the series. On July 7 yellows began to appear in the sterilized inoculated flat and continued to spread until July 16, when the experiment was concluded by making plates from the plants from the sterilized inoculated, and the sterilized flats. *F. conglutinans* was found as the cause of the yellowing in all the plants, while the control plants remained sterile. This is shown well in pl. 2, figs. 15 and 16. Exact counts were not made.

Again, on June 29, four pots of sterile greenhouse soil were inoculated with cultures of *F. conglutinans,* and on July 24 yellows was found in all four of the pots. On July 11 inoculations of individual plants were repeated by dipping wounded plant roots into suspensions of the spores of the fungus in sterile water. Adequate controls were included in this series and in all cases the control plants remained healthy, while among the inoculated plants, 50 per cent of the individuals showed the characteristic symptoms on July 24, when the experiment was discontinued.

VIRULENCE OF CULTURES

Pure cultures of *F. conglutinans* vary greatly in their virulence, and the cause of this variation is not certain. From inoculation experiments it would seem that, in general, the longer the organism has been carried in culture the greater is the probability that it has lost its virulence. On the other hand, drying in culture seems to have little or no ill effect on the virulence of the organism.

The susceptibility of the host must also be considered as an important factor when the fungus-host relation hangs in such a delicate balance, and the source of the culture is always

of importance also. The medium upon which the culture is grown and the state of the mycelium and spores have been pointed out by Wollenweber as important factors in other species of *Fusarium* which produce plant disease, and doubtless they bear their part in the irregularity of the results presented here.

In a series of inoculation experiments made at the Missouri Botanical Garden, recently isolated cultures were used as sources of infection. The cultures were grown on cooked potato stems, and inoculation was effected by placing a bit of the culture tissue in contact with a wound on the hypocotyl of the plant. The plants were in the cotyledonous stage, and after inoculation were placed in normal uninfected greenhouse soil. Five seedlings were placed in each pot. Table IV gives the results of the experiments.

TABLE IV

PRELIMINARY STUDY OF VARIATION OF VIRULENCE OF FUSARIUM CONGLUTINANS IN PURE CULTURE

Culture number	Date of isolation	Total no. of plants	No. of diseased plants	Per cent of diseased plants
XVI	7/14/13	40	30	75.0
LV	11/17/14	15	13	86.6
LVI	2/1/15	5	5	100.0
Control	.....	10	0	0.0

It will be noted that where the larger number of plants was used the percentage of infection fell. This result might have been expected if the age of the cultures used and the great variation in susceptibility of the host plant were taken into consideration, but to gather more data on these points a trial was made with a large series of cultures that had been isolated at various times and also from various sources.

Table V gives the data on the inoculation experiment which was carried out similarly to the one just reported.

TABLE V
RESULT OF INOCULATION EXPERIMENT SHOWING VARIATIONS IN VIRULENCE OF FUSARIUM CONGLUTINANS IN PURE CULTURE

Culture number	Species	Source	Date of isolation	Pathogenicity					
				Damped off		Yellowed		Healthy	
				No.	Per cent	No.	Per cent	No.	Per cent
I	*F. conglutinans*	Cabbage	5/16/13	0	0	0	0	5	100
II	*F. conglutinans*	Cabbage	6/12/13	0	0	0	0	5	100
V	*F. conglutinans*	Cabbage	5/10/13	1	20	3	60	1	20
VI	*F. conglutinans*	Cabbage	5/10/13	1	20	0	0	4	80
IX	*F. conglutinans*	Cabbage	7/14/13	0	0	0	0	5	100
X	*F. conglutinans*	Cabbage	7/14/13	1	20	1	20	3	60
XI	*F. conglutinans*	Cabbage	7/14/13	5	100	0	0	0	0
XIII	*F. conglutinans*	Cabbage	7/14/13	0	0	2	40	3	60
XIV	*F. conglutinans*	Cabbage	7/14/13	0	0	0	0	5	100
XVI	*F. conglutinans*	Cabbage	7/14/13	0	0	4	80	1	20
XVII	*F. conglutinans*	Cabbage	7/28/13	0	0	0	0	5	100
XVIII	Undetermined	Cauliflower	7/26/13	0	0	0	0	5	100
XIX	*F. conglutinans*	Cabbage	5/ 6/13	0	0	3	60	2	40
XX	*F. conglutinans*	Cauliflower	7/26/13	0	0	2	40	3	60
XXI	*F. conglutinans*	Cabbage	7/26/13	0	0	0	0	5	100
XXII	*F. conglutinans*	Cabbage	7/26/13	0	0	0	0	5	100
XXIII	*F. conglutinans*	Cabbage	7/26/13	0	0	0	0	5	100
XXIV	*F. conglutinans*	Cabbage	7/26/13	0	0	0	0	5	100
XXV	*F. conglutinans*	Cabbage	7/27/13	4	80	1	20	0	0
XXVI	*F. orthoceras*	Cabbage	5/ 6/13	0	0	0	0	5	100
XXVII	Undetermined	Cabbage	8/ 4/12	0	0	0	0	5	100
XXVIII	*F. conglutinans*	Cabbage	8/ 4/12	0	0	0	0	5	100
XXIX	Undetermined	Cauliflower	8/24/12	0	0	0	0	5	100
XXX	*F. conglutinans*	Cabbage	6/28/12	0	0	3	60	2	40
XXXII	*F. conglutinans*	Cabbage	6/28/12	1	20	4	80	0	0
XXXIII	Undetermined	Cabbage	6/28/12	2	40	0	0	3	60
XXXV	*F. conglutinans*	Cabbage	8/24/12	1	20	0	0	4	80
XXXVI	*F. conglutinans*	Cabbage	6/24/12	2	40	0	0	3	60
XXXVII	*F. conglutinans*	Cabbage	6/28/12	1	20	1	20	3	60
XXXVIII	*F. conglutinans*	Cabbage	6/28/13	0	0	0	0	5	100
XXXIX	*F. conglutinans*	Cabbage	6/28/13	1	20	0	0	4	80
XL	*F. conglutinans*	Cauliflower	1/ 3/14	5	100	0	0	0	0
XLII	*F. conglutinans*	Cabbage	2/14/14	2	40	2	40	1	20
XLIII	Undetermined	Aster	.....	1	20	0	0	4	80
XLIV	*F. conglutinans*	Aster*	.....	0	0	0	0	5	100
XLV	*F. conglutinans*	Potato*	.....	3	60	0	0	2	40
XLVI	*F. conglutinans*	Cabbage	4/13/14	1	20	0	0	4	80
XLVII	*F. conglutinans*	Cabbage	3/12/14	0	0	3	60	2	40
LI	*F. conglutinans*	Cabbage	5/ 6/14	0	0	0	0	5	100
LII	*F. conglutinans*	Cabbage	5/ 6/14	0	0	2	40	3	60
LIII	*F. conglutinans*	Cabbage	5/18/14	0	0	2	40	3	60
LIV	Undetermined	Cabbage	9/24/14	0	0	0	0	5	100
LV	*F. conglutinans*	Cabbage	11/17/14	0	0	4	80	1	20
LVI	*F. conglutinans*	Cabbage	2/ 1/15	0	0	5	100	0	0
Control	No fungus	.....	.....	1	10	0	0	9	90

*Isolated by Lewis ('13) at the Maine Agricultural Experiment Station and determined by H. W. Wollenweber, Bureau of Plant Industry, Washington, D. C.

The cultures were all prepared in the same way for the experiment. They were all grown on cooked potato stems, and were of the same age. Each culture was used to inoculate five plants by inserting a bit of the mycelium into the hypocotyl of young seedlings still in the cotyledonous stage.

The previous history of the cultures, of course, differed for the individual. Cultures VI, XVII, and XIX had been allowed to dry out on potato hard agar for fourteen months, that is, from July 14, 1913, to September 26, 1914, and then were transferred to cooked potato stems. On January 12, 1915, they were again transferred to fresh cooked potato stems, and these cultures were used in the experiment. Although two of them (VI and XVII) apparently lost their virulence, the third (XIX) retained its ability to attack the host even after this severe drying. Other strains which had not been allowed to dry out but which were kept on fresh media, possessed no greater virulence, nor did any greater percentage of them exhibit pathogenicity.

The length of time the organism has been in culture seems to be a more important factor; for cultures isolated late in 1914 showed proportionally a larger number virulent than did those isolated at earlier dates. In addition, the more recent isolations showed the greater virulence. That this is not invariable, however, is shown by the fact that many of the cultures first isolated still retained their virulence, viz., XXX, XXXII, XXXVII, all three of which were isolated on June 28, 1912.

The source of the culture seems to have greater influence. Of the six strains of *F. conglutinans* isolated from cauliflower grown in diseased soil and apparently attacked with yellows, but one (XX) showed any ability to infect cabbage and that only to a limited extent. Strains from aster and potato, kindly furnished by Dr. W. J. Morse of the Maine Agricultural Experiment Station, also gave negative results when inoculated into cabbage. *F. orthoceras*, which had been isolated from the stem of a diseased cabbage plant, was introduced into the series as a control. A number of undetermined Fusarium cultures which had been isolated from cabbage, cauli-

flower, and China aster were added for the same reason. None of these latter were capable of infecting the living cabbage plant.

SUSCEPTIBILITY OF HOST

That the susceptibility of the host plant must also play an important part in this question of inoculation is shown by the fact that so few of the cultures gave a perfect (100 per cent) infection, although the inoculations were made with parts of the same culture on plants from the same pot and under as identical conditions as possible.

Further evidence on this point was also shown when the difference in the length of the incubation period of any one culture was noted on plants of the same variety and age. For example, in the last experiment observations were made daily in the greenhouse, and the condition of the plants noted. The results of these observations are brought together for a few of the cultures in table VI.

TABLE VI

RESULTS OF OBSERVATIONS ON INDIVIDUAL SUSCEPTIBILITY AS SHOWN BY THE INCUBATION PERIOD UPON INOCULATION

Culture no.	Number of diseased plants in each pot at the various days of incubation						
	15	16	17	19	23	40	50
XVI	1	2	3	3	3	3	4
V	.....	2	2	2	3	3	3
XIX	.....	.....	2	3	3	3	3
XLII	.....	.....	1	1	4	4	4
XXX	.....	.....	.....	2	3	3	3
XXXII	.....	.....	.....	1	2	3	4
Control	.....	.....	.....	.....	.....	.....	.....

Thus it is shown that not only were some virulent cultures slower in taking effect than others, but that the individual plants were markedly different in their ability to resist the fungus. Although what constitutes such resistance has not been worked out, a little evidence gathered during these investigations may well be presented here.

In the field it was noted that the plants of the resistant strains of cabbage were, as a rule, larger than plants of the commercial strains of the same age. The first year it was thought that this difference in size might be due to crowding in the seed-bed of the plants of the commercial strain, chiefly because the amount of available seed of the resistant varieties was limited, while that of the commercial strain was plentiful. When this fact repeated itself over three years, experiments in the laboratory were run to account for the difference. Seeds were placed between moist filter paper in petri dishes and allowed to germinate. Twenty-five seeds were placed in each dish, and two dishes of each strain, VIII a-16 and commercial Danish Ball-head, were germinated. After wetting up the filter paper with distilled water the dishes were all placed in an incubator at 22°C. The seeds of the resistant strain germinated twelve hours before those of the commercial varieties, three days after the beginning of the experiment. Plate 2, figs. 5 and 6 give an idea of the appearance of the seedlings at this time, under similar conditions of moisture and temperature.

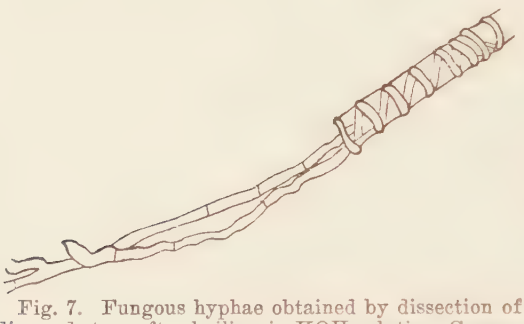


Fig. 7. Fungous hyphae obtained by dissection of diseased stem after boiling in KOH solution. Camera lucida sketch.

This characteristic of growth suggested that there might be a considerable difference in osmotic pressure between the root cells of the two strains, and experimental work was undertaken to determine whether the threshold of plasmolysis of the two strands differed toward NaCl solution as a plasmolytic agent. Two trials were made using the root-hairs as indicators, but in neither case was any difference between the threshold of plasmolysis of the resistant strain and that of the susceptible strain found.

Host Relations

MORPHOLOGY

The distribution of the fungus in the living host tissues is limited to the vascular bundles. This fact was first shown in making plates from old stems of diseased plants. The stems were cut cross-wise in thin sections and, after sterilization in hydrogen peroxide for five minutes and washing in sterile water, were laid on the surface of poured plates of potato hard agar. Invariably the first growth of the mycelium appeared from the fibro-vascular ring (pl. 2, fig. 14). Upon dissection of diseased seedlings the hyphae were demonstrable

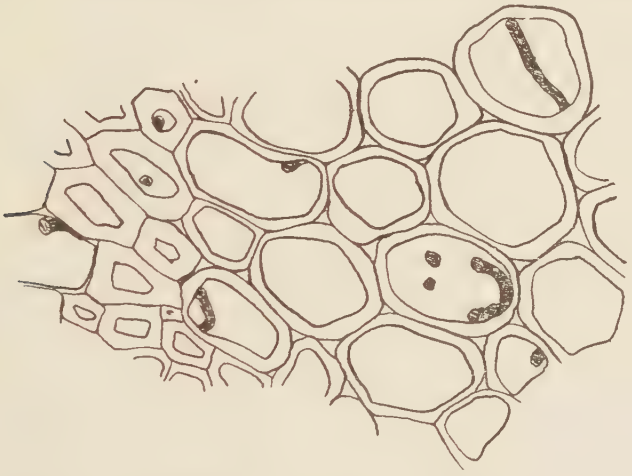


Fig. 8. Cross-section of vascular bundle from diseased cabbage stem, showing distribution of fungus in vessels. Note preponderance of cut ends of hyphae. Stained with Pianeze IIIb. Camera lucida sketch × 1000.

traversing the lumina of the bundles longitudinally. The stems were first boiled for five minutes in a 5 per cent potassium hydroxide solution and then dissected under a hand lens. The final examination was made under the compound microscope. In no case was a very large amount of mycelium found in any single vessel (fig. 7).

In later work the diseased stems were imbedded in paraffin in the usual manner, after fixing in Gilson's solution, and stained with Pianeze IIIb, as recommended by Vaughan ('14). The fungus stained a deep red, while the host tissue was col-

Fig. 9. Longitudinal section of vessel in diseased cabbage stem, showing vegetative hyphae. Stained with Pianeze IIIb. Camera lucida sketch × 1000.

ored green. Longitudinal sections showed the hyphae of the fungus running longitudinally in the lumina of the spiral vessels and the bast fibres. Cross-sections showed only the cut ends of the fungus. Drawings illustrating these facts are shown in figs. 8 and 9 which were made with the aid of a camera lucida. It was found that besides the purely vegetative hyphae, the fungus produced conidia in the vessels of the host (fig. 10). Those spores observed in the host tissue were all of the unicellular type.

All the evidence shows that the fungus attacks the root first, but just how remains to be worked out. After entering the host, it is confined to the vascular system. The fungus was never isolated from the stem until after a marked yellowing of the leaves appeared, although it was always present in the tissues before they had been killed. This fact is brought out in pl. 2, fig. 12 in which is shown a branched plant, one branch of which was attacked, while the other remained healthy in appearance. The leaf at *E* was still alive although one side of it was yellow. The stem of the plant appeared normal externally. The fungus, however, was isolated from the stem below the branching and at the points *D* and *E* on the diseased branch, while the parts at *B* and *C* on the other branch remained sterile. The plate made from this plant is shown in pl. 2, fig. 13.

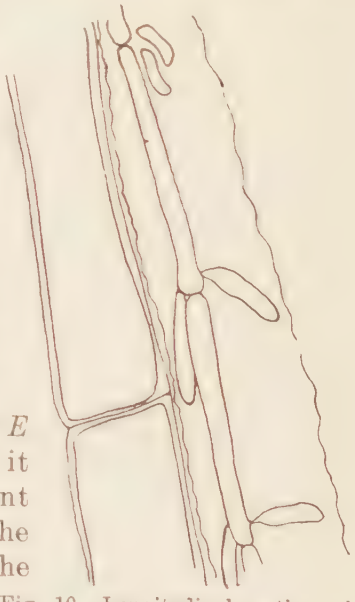


Fig. 10. Longitudinal section of vessel in diseased cabbage stem, showing production of conidia. Stained with Pianeze IIIb. Camera lucida sketch × 1000.

After the death of the host the fungus traverses all the tissues, sporulating at the surface and within the host also. In this way the fungus is able to return to the soil. Whether it may winter over in the host tissue was tested by marking plants which have been killed by the yellows in the field in 1913, and then bringing these plants into the laboratory in the spring of 1914. The stumps were first freed from the soil by brushing them under water and then washing in running water for fifteen minutes. After this washing the stalks were divided into equal portions and placed in two flats of sterile greenhouse soil (sterilized in the autoclave at eleven pounds pressure for five hours) and left for twenty-four days, after which time the flats were planted to cabbage on June 3, 1914. Yellows was found in both flats on July 6, 1914, showing that the fungus was able to get back into the soil from these stems, or that the roots coming in contact with the stems were attacked.

Fig. 11. Conidia obtained from over-wintered cabbage stem in spring of 1915. Camera lucida sketch × 800.

Fig. 12. Conidia obtained from a second stem of over-wintered cabbage. Camera lucida sketch × 800.

That the fungus may live over in the soil was first shown by E. F. Smith ('99, '99[a]), when he found that the organism in the soil was able to withstand drying in the laboratory for three and one-half years. Dr. M. P. Henderson in some unpublished studies on *Phoma lingam* showed inadvertently that the stumps of cabbage are not necessary for the transmission of *Fusarium conglutinans*, as it is able to live in the soil. He found that *F. conglutinans* was still present and virulent in soil that had been sifted through a fine sieve.

This experiment was repeated with soil from the experimental field at Racine. The soil was sifted through a 40-mesh sieve and in this earth cabbage was then planted. All the plants were found diseased at the end of fourteen days, while the plants in a control pot of uninfected soil remained healthy. Plants in a pot of infected soil, unsieved, showed the disease slightly earlier, at the end of twelve days, this difference in time being due probably to the fact that in the sieved soil the organism existed only as spores and, therefore, took longer to infect than where it grew rapidly from mycelium in the old host tissue.

TEMPERATURE

Literature.—Before discussing the significance of the temperature relation in the case of the attack of *F. conglutinans* on cabbage, the results obtained in other diseases where temperature has proven of pathological importance should be considered briefly for comparison.

Upon making a careful review of the literature it was found that our knowledge of this field is very limited and fragmentary, although the importance of temperature is generally recognized. Earle ('02), in a paper on the environmental factors concerned with disease, discussed the temperature relations in a general way, pointing out that for health, the plant must have temperatures of the proper degree for growth. Duggar ('09) also recognized the importance of temperature in relation to the susceptibility of the host to fungous attack, but in a paper of this nature he could make nothing more than a general statement. Reed ('10) in a similar paper paid more attention to this one of the many environmental factors involved, and showed that the temperature most favorable for the attack of a fungus is dependent entirely on the particular organism under consideration. He cited as examples of this relation the bitter rot of apple which is favored by high temperatures and the leaf curl of the peach which thrives best under cool weather conditions. Klebahn ('12, p. 88) stated that, although the temperature is undoubt-

edly an important factor in the case of diseases caused by the fungi, there has been insufficient work on the question to warrant more than a general discussion of the subject.

In spite of this lack of correlated facts on the relation of temperature to plant disease, there are many isolated notes scattered through plant pathological literature, and an attempt has been made to bring them together at this time. In order to put them in the best shape for comparison, one with another, it was thought well to arrange them according to the natural grouping of the parasites upon which the observations were made.

Schizomycetes.—The diseases caused by bacteria may be placed first. Halsted ('98) pointed out that the summer of 1894, which was excessively hot in New Jersey, was characterized by an outbreak of fire blight due to *Bacillus amylovorus*. Whetzel ('06), from evidence in New York, confirmed this relation but considered that moisture was the more important factor limiting the outbreak of an effective epidemic of this disease.

Schuster ('12), working with the bacterial rots of potato, showed that at high temperatures (35°C.) saprophytic species, as, for example, *Bacillus fluorescens*, might become parasitic on potato tubers, causing soft rot.

Smith ('14) noted that in rapidly growing shoots of susceptible hosts the incubation period of *Bacillus Solanacearum* is shortened in very hot wet weather from 8–10 days to 2–3 days. He attributes the decrease to a difference in susceptibility in the host rather than to a change in the virulence of the invading organism.

Phycomycetes.—Perhaps more work has been done on the temperature relations of the *Phycomycetes* than of any other group of fungi, but the major part of these studies has been with its relation to spore germination.

Atkinson ('95) found that high temperature was a contributing factor to damping off by *Pythium deBaryanum*, which view is corroborated by Johnson ('14) working at Wisconsin, although neither of these authors show any experimental evidence to support their opinion.

Melhus ('11) showed that chilling the conidia of *Cystopus candidus* to a temperature of 8–10° C. produced the optimum germination and also infection in the case of the radish, and thus proved that this fungus is dependent on such chilling for its best development in its attack on the host.

Similar relations have been found to hold true in the cases of other *Phycomycetes*. From field observations covering a period of twenty years Lutman ('11) concluded that *Phytophthora infestans* required a fall in temperature for its best development on the potato. Melhus ('12) showed that the optimum temperature for spore germination in this species, both conidia and zoospores, was 8–14° C., thus corroborating the previous field observations. After the fungus has entered, however, he noted in a later paper ('13) that the disease was produced more readily at comparatively high temperatures, thus showing that, in this case at least, there was a difference between the temperatures favorable to parasitic growth, depending upon whether the infecting material be spores or mycelium.

Reed ('12), working with *Phytophthora infestans* on tomato plants, found that here again its attack was dependent upon low temperatures. The attack only occurred above the altitude of 2000 feet, and then only at times when there were cool nights.

Opposed to *Phytophthora*, *Plasmopara Viticola* has been found to be dependent on a rather high degree of temperature. Sajó ('01) observed this in 1900 as compared with 1899, the temperature in 1900 being higher throughout the summer than in the previous year. Again, in 1912, Ravaz and Verge ('12, '12[a], '12[b]) showed that for quickest germination a temperature of 22–27° C. was necessary for this fungus and that, since the fungus found water also necessary for infection, the host could only be attacked at periods of sustained high temperatures and humidity. Istvánffi and Pálinkás ('13) showed that not only were Ravaz and Verge correct, but that the development of conidiophores and conidia from the infected host was also somewhat dependent on these same temperatures.

Ascomycetes.—In the *Ascomycetes* but little has been done on the temperature relations of the parasitic forms. In Ohio, Selby ('99, '04) observed that the leaf curl of the peach, caused by *Exoascus deformans*, was favored in its occurrence by relatively low temperatures in April, May, and June, the weather in April having the greatest influence. These conclusions were based on observations made over a period of ten years, 1893–1903. Duggar ('09) showed that the same was true in New York. Pierce ('00) found that similar conditions brought about the attack in California, and attributed the virulence of the attack to the harmful action the adverse weather had on the host, causing it to be weakened. He also noted that hot dry weather would check an attack which had already started.

That *Sclerotinia Panacis*, the cause of black rot of the ginseng root, was favored by cold weather was shown by Van Hook ('04). This author found that this disease developed only in the winter, also a time when the roots were in a dormant state.

Germination of the spores of *Sphaerotheca Humuli* has been shown by Salmon ('00) to be increased if the spores were previously exposed to cold, especially freezing, temperatures. The germination, however, took place only when the higher temperatures were restored. Sajó ('01) observed that *Oidium Tuckeri* on grapes was favored by subnormal temperature and moisture.

Probably one of the first observations of scientific value on the relation of temperature to a particular plant disease was that made on the black rot of grapes by Buchanan in 1850. As is reported by Viala ('87), Buchanan noticed that this disease was worse after a period of hot weather. Viala also made observations on this relation and found that in hot weather (maximum 35–37°C., minimum 18–20°C.) there was a bad epidemic of the trouble. When the temperature fell the disease became checked. His observations covered a period of two years. Later Edson ('03), making observations in North Carolina, came to similar conclusions.

That reaction of different parasites to the temperature relations may differ even within a single genus, is well brought out in the genus *Glomerella*. Here, on the one hand, is found *Glomerella rufomaculans* which is dependent on a maximum temperature of 32°C. for the outbreak of an epidemic (Scott, '06), while on the other, *Colletotrichum Lindemuthianum* (*Glomerella Lindemuthianum* Shear) is reported by Edgerton ('15) as being unable to grow in culture above 31°C. He shows that this species causes the most severe injury at cool temperatures, infection being inhibited by the summer heat.

Fungi Imperfecti.—Little has been done as to this relation in the *Fungi Imperfecti*. Ravn ('00) has shown that in the case of *Helminthosporium teres*, the attack on barley was conditioned on cool temperatures at the immediate time of sprouting of the kernel in the soil. Similar conditions held for the stripe disease of barley, caused by *Helminthosporium gramineum*. By growing the plants under controlled conditions of temperature, this author was able to show that a temperature of 6.5–14°C. favored the disease, while a temperature of 19–25°C. practically excluded it from the seed beds. He showed that the susceptible period for infection was immediately at the time of germination of the seedling, and that plants sprouted in warm temperatures, which were then immediately removed to cool conditions, did not become infected. Bakke ('12), in Iowa, showed that the optimum for growth of this fungus in culture was 23–25°C., so that it would appear that the effect of the temperature was one of resistance or escape on the part of the host rather than an effect on the fungus. Further evidence bears out this belief, since *Helminthosporium teres* can cause a leaf spot in the field at the higher temperatures.

The question of the temperature relations of the parasitic species of *Fusarium* will be discussed later and may be dismissed here with a brief statement that, as a rule, they seem to require high temperatures for their most virulent attack. In this they appear to be opposed to the closely related genus, *Verticillium*, which also causes wilt diseases (Wollenweber, '13).

In one other member of the *Fungi Imperfecti, Sphaeropsis Ellisii,* Petri ('13) has observed that the attack was dependent on cool humid atmospheric conditions, and the fungus was never seen in warm well-ventilated exposures. It is probable, however, that in this disease the limiting factor is moisture rather than temperature.

Basidiomycetes.—The temperature relations of the smuts and the rusts have been worked out more exactly than the other *Basidiomycetes.* Brefeld ('95), in experiments with oat smut (*Ustilago Avenae*), showed that when germinated spores were placed in soil and oats grown therein, 27–30 per cent of the plants became infected at 15°C., while at 7°C. 40–46 per cent were attacked. Tubeuf ('01), working with the same form, found the opposite results when ungerminated spores were used instead of germinated. He showed also that the spores of *Ustilago Avenae* cannot germinate under 5°C., their minimum for germination being between 5 and 9°C. As is pointed out by Hecke ('09), the difference in the findings is probably due to the fact that Brefeld germinated the spores before exposing the cultures to the different temperatures while Tubeuf did not. On account of this difference the time of susceptibility of the host was lengthened by the low temperature in Brefeld's experiments, and hence the increased infection; while in the experiments of Tubeuf the plants at low temperatures were held below the temperature of germination of the smut spores, and, therefore, the greater infection occurred at the higher temperatures.

In regard to the stinking smut of wheat (*Ustilago Tritici*), on the other hand, the minimum temperature for germination of both the wheat kernel (3–4°C.) and the spores of the fungus (5°C.) was practically the same, while the maximum for the smut germination (25°C.) was considerably lower than that of the wheat (30–32°C.), so that in this case the opposite facts were true, as Hecke ('09) showed. Therefore, the infection was favored by low temperatures and prevented by high (25°C.), because when the plant grew slowly the length of the susceptible period was increased. Munerati ('12) reports similar observations on wheat in Italy; early fall and

late spring planting favored the host, while late fall and early spring planting increased infection.

Among the rusts a similar relation between spore germination and infection occurs. Howell ('90), working on the clover rust (*Uromyces Trifolii*), showed that infection would take place only at comparatively low temperatures, the reason given being that it was only at the low temperatures that spore germination occurred; the maximum temperature for both uredo- and accidiospores was in the neighborhood of 25°C. Marshall Ward ('01) in his notable experiments with the brome rust (*Puccinia dispersa*) showed that the optimum temperature for germination for this form was also at 18°C.

Eriksson ('95), in making experiments with rusts, and especially with the germination of spores of different forms, found that chilling the spores in the case of *Aecidium Berberidis, Peridermium Strobi, Uredo glumarum,* and *U. coronata* accelerated germination when they were brought back to higher temperatures. Johnson ('12), working with uredospores of *Puccinia graminis, P. rubigo-vera,* and *P. coronata,* showed that their optimum temperatures for germination were 12–17°C.; hence epidemics of grain rusts usually spread at periods of subnormal temperatures. From these observations it is easily seen that the rusts have developed the parasitic habit to a very special degree, adapting the temperatures when there is likely to be dew as those at which spore germination will take place, and thus aiding themselves in their attack on the host.

Balls ('08) has shown in some very careful work on the temperature relation of the *Rhizoctonia* causing "sore shin" of cotton that this fungus attacks the cotton plant at 20°C., but not at 33°C. He checked his work with observations on pure cultures of the organism, and found that at high temperatures the fungus secreted, or excreted, an inhibiting substance into the culture fluid which was injurious to the fungus. Whether this same toxic substance prevented that attack on the host is questionable.

As to the wood-destroying fungi, Falck ('07) found that *Merulius silvester, M. domesticus, M. sclerotiorum, Polyporus*

vaporarius spumarius, and *Verpa bohemica* all have a minimum temperature for growth of about 3°C.; *Merulius silvester*, *M. sclerotiorum*, and *Polyporus vaporarius spumarius* have an optimum of about 25°C., while the optimum for *Merulius domesticus* and *Verpa bohemica* is at 22° C. Their maxima are all at about 30°C. It was noted that these temperatures correspond very closely to those of *Phycomyces nitens* and *Mucor Mucedo*, as determined for comparison, although each species has a rate of growth that is constant for a given temperature (other factors being equal) and characteristic of that species.

With the exception of the genus *Fusarium*, the preceding covers the important work that has been done on the temperature relation of the parasitic fungi, as far as could be ascertained. It will be readily seen that the relation of temperature to the attack of a parasite is a complex one and depends entirely upon the individual diseases under observation.

To take up now the relations of temperature to diseases caused by *Fusarium*, Jones ('08) stated in his observations on the damping off of coniferous seedlings, caused by a member of that genus, that the trouble was facilitated by high temperatures. He was confirmed in this by Gifford ('11), working on the same trouble. Wollenweber ('13), however, was the first to show this relation in the case of the wilt diseases caused by *Fusarium*. He pointed out that these diseases occur most severely in the warmer climates, especially in the tropics and subtropics, but noted the cabbage yellows as an exception to this general rule. Previously, Wolf ('10) had noted, in the case of the wilt disease of pansy (*Fusarium Violae*), that the trouble was found only in July, and then only when the beds in which the plants were growing had been heavily covered with fresh horse manure, both of which facts suggest a dependence of the fungus on high temperature. This author made no mention of temperature, nor were any experiments on this relation reported.

Orton ('13, '14) in discussing the potato plant and its relation to disease has shown that in this instance Wollenweber's hypothesis held true, the Fusarium wilt having a southern

range as compared with *Verticillium albo-atrum* which caused a trouble of almost identical nature in the northern climates. Neither of these authors made controlled experiments to determine, if possible, exact ranges of temperatures.

Humphrey ('14), working in Washington with tomato blight caused by *Fusarium orthoceras* App. and Wollenw. and *F. oxysporum* Schlecht., found that the blight was favored by high temperatures. His statements were based on observations made on experimental plots in 1911 and 1914 at Pullman, Washington, coupled with the determination of the optimum temperature for growth of the organism in the laboratory at 86°F. or 30°C. This author suggested that the light intensity and wind are also factors in bringing about the typical symptoms of the disease.

A preliminary report (Gilman, '14) of the relation of temperature to the occurrence of cabbage yellows was made at the Philadelphia meetings of the American Phytopathological Society in 1915. The full report of this work is as follows:

Field observations.—On the experimental plot at Racine during the summer of 1912 it was observed that the attack of *F. conglutinans* occurred in the early part of July, when the plants had been set about two weeks. It was noted further that the plants which escaped or withstood the disease at this time remained healthy throughout the rest of the summer. Plants set out after this period were all practically immune. Upon looking up the temperature records of the summer it was found that the attack of the disease followed very closely a period of exceptionally hot weather. Table VII gives a summary of the observations made at three different times during the growing period. The strain numbers are those used by Jones and Gilman ('15) in the development of a variety of cabbage resistant to yellows. Strains II, III, and VI were commercial varieties of Danish Ball head imported from Denmark; strains VII, VIII, IX, and X were from seed grown from resistant heads; strain XI was of the Flat Dutch variety imported from Germany; strain XII was commercial Houser; and strain XV, commercial Danish Ball-head. Further details may be found in the publication mentioned above. The

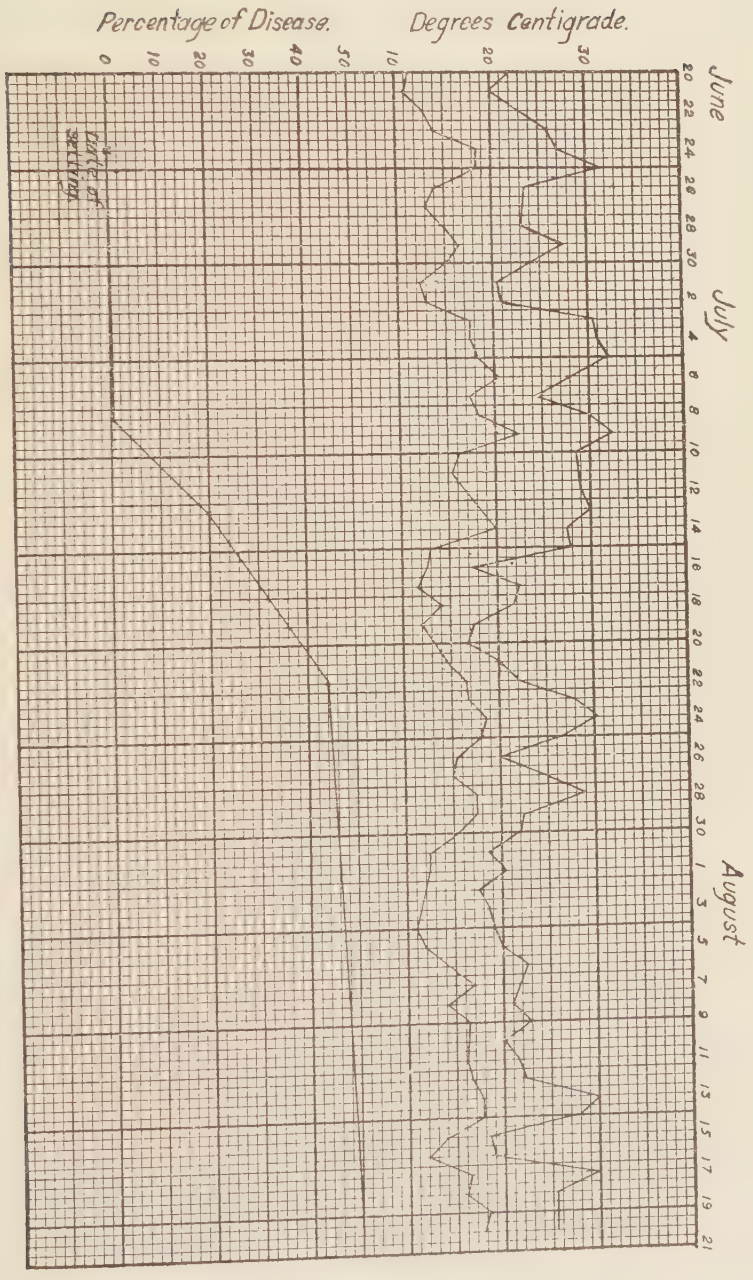


Fig. 13. Comparison of temperature with percentage of disease in field in 1912.

plants were set in the field June 24. The disease was beginning to show on July 8, when only 0.05 per cent of the plants were yellowed, and increased rapidly to 40.5 per cent on July 22. Of 420 plants set on July 15, after the hottest weather had passed, all remained healthy to August 21, but on account of the late planting did not make heads, and, therefore, were not considered later. The curves given in fig. 13 show the relation of the occurrence of the disease to temperature. The temperature data from which these were plotted are those published by the Milwaukee office of the United States Weather Bureau, a distance 25 miles north from the experimental field.

TABLE VII

SUMMARY OF FIELD OBSERVATIONS ON EXPERIMENTAL PLOT AT RACINE, WISCONSIN, 1912

Strain	Total no. of plants	July 16		July 22		August 20	
		Number yellow	Per cent yellow	Number yellow	Per cent yellow	Number yellow	Per cent yellow
II	45	18	4.0	32	71.1	37	82.2
III	45	3	6.6	24	53.3	32	71.1
VI	44	24	54.5	35	79.5	43	95.4
VII (a-y)	1039	284	27.3	551	53.0	567	54.6
VIII (a & b)	89	1	1.1	21	23.5	11	12.3
IX (3-116)	352	31	8.8	130	36.9	191	54.3
X (101-143)	625	97	15.5	195	31.2	234	37.4
XI	43	12	27.9	27	62.8	32	74.4
XII	39	5	12.8	18	46.1	17	43.6
XV	29	8	27.6	19	65.5	20	68.9
Total	2350	483	20.5	1052	40.5	1184	50.3

Again, in 1913, observations were made in the field on the same plot. The results of these observations are given in table VIII and fig. 14. Besides the strains used in 1912 several new commercial sorts were introduced. Strains XIII and XIV were Danish Ball head bred locally, XIII being short-stemmed and XIV long stemmed; strain XVI was Danish Ball-head grown by the Ferry Seed Company; XVII was All Season; XVIII, Succession; XIX, Volga; XX, Early Jersey Wakefield; XXI, Copenhagen Market; XXII, Early Summer; XXIII, Charleston Wakefield. While the experience of the

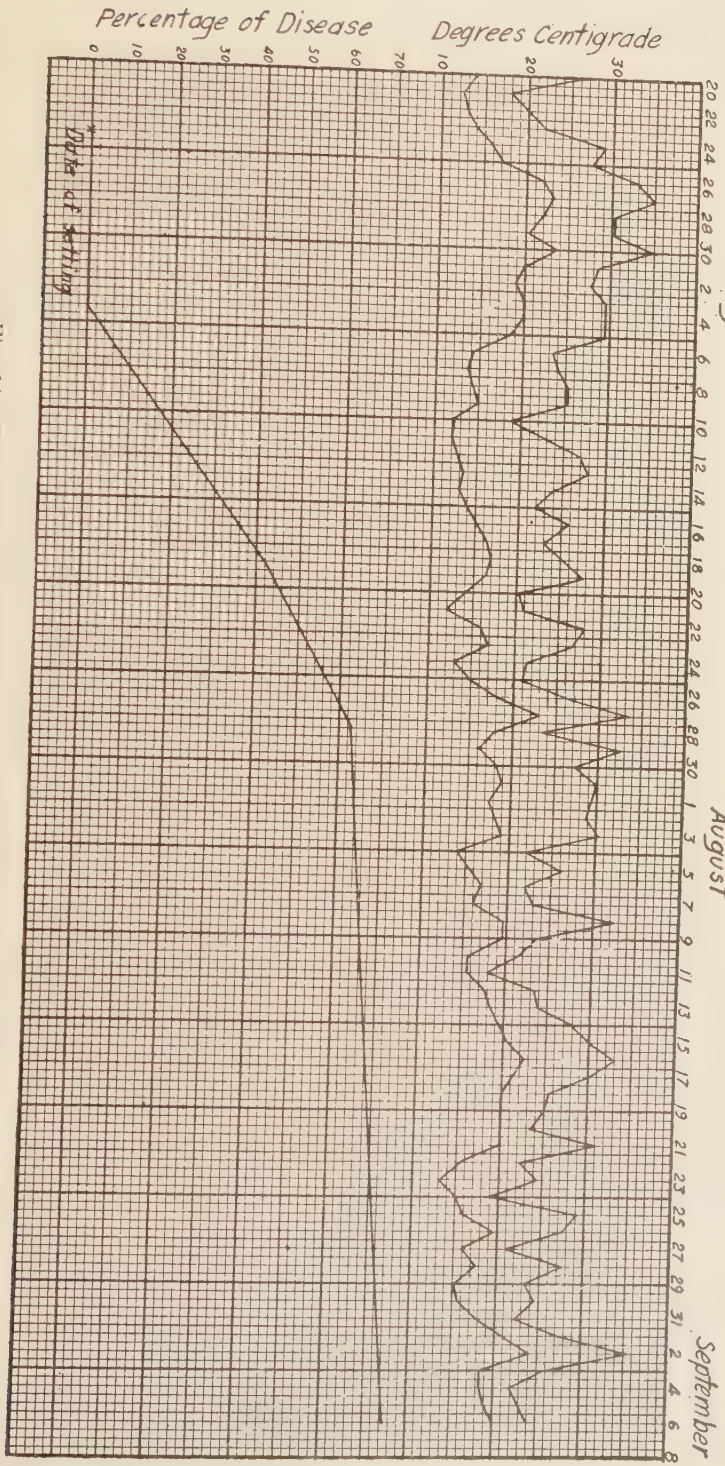


Fig. 14. Comparison of temperature with percentage of disease in field in 1913.

previous year was repeated, the relation between temperature and the attack was not as marked as it had been in 1912. The higher temperatures were sustained for a longer time, and, therefore, the percentage of disease continued to rise throughout the summer. The plants were set June 24, and no disease was found on July 4. Nevertheless, the main attack occurred in practically the same relation to the hottest weather as it had the previous year.

In 1914 the plants were grown on two experimental plots, and in addition to the strains mentioned above, a resistant strain from the Maryland Agricultural Experiment Station (XXIV) was added. The plants were set on June 26, and the disease was first observed on July 16, when 1.5 per cent of the plants showed the typical yellowing. Tables IX and X summarize the observations that were made during this summer.

TABLE VIII

SUMMARY OF FIELD OBSERVATIONS ON EXPERIMENTAL PLOT AT RACINE, WISCONSIN, 1913

Strain	Total no. of plants	July 19		July 28		September 6	
		Number yellow	Per cent yellow	Number yellow	Per cent yellow	Number yellow	Per cent yellow
II	50	28	56.0	42	84.0	47	94.0
III	46	28	60.8	34	73.9	34	73.9
VI	46	25	54.3	29	63.0	45	97.8
VII (a-y)	1243	639	51.4	874	70.3	795	63.9
VIII (a & b)	96	3	3.1	8	8.3	9	9.4
IX (3-116)	248	77	31.0	120	48.4	98	39.5
XI	47	19	40.4	21	44.7	33	70.2
XII	37	17	45.9	24	64.8	24	64.8
XIII (1-19)	820	301	36.7	489	59.6	748	91.0
XIV (1-11)	565	140	24.7	256	45.3	504	89.2
XV	985	556	56.4	707	71.7	827	83.9
XVI	43	11	25.6	25	58.1	42	97.6
XVII	40	17	42.5	26	65.0	32	80.0
XVIII	28	19	67.8	20	71.4	26	92.8
XIX	42	15	35.7	17	40.5	12	28.5
XX	38	15	39.4	17	44.7	28	73.6
XXI	39	20	51.3	23	58.9	37	94.8
XXII	39	14	35.9	11	28.2	16	41.0
XXIII	33	17	51.5	17	51.5	23	69.7
Total	4485	1961	44.3	2760	51.9	3380	63.5

TABLE IX

SUMMARY OF FIELD OBSERVATIONS ON EXPERIMENTAL PLOT, HANSCHE FARM, RACINE, WISCONSIN, 1914

Strain	Total no. of plants	July 16		July 30		August 17	
		Number yellow	Per cent yellow	Number yellow	Per cent yellow	Number yellow	Per cent yellow
VIIf (1-9).....	162	3	1.85	46	28.40	54	33.33
VIIi (5-7).....	161	2	1.24	40	24.83	57	35.40
VIIIa (7-35)....	810	0	0.0	8	0.99	10	1.23
VIIIb (3-14)....	385	0	0.0	8	2.08	19	4.94
X 135.....	81	0	0.0	9	11.11	16	19.75
X 143.....	81	0	0.0	8	9.87	15	18.50
X 135 (2-33)...	782	3	0.38	145	18.54	168	21.48
X 143 (2-38)...	1213	2	0.16	215	17.72	318	26.22
XV.....	482	27	5.6	374	77.59	433	89.83
XVI.....	299	5	1.67	144	48.16	236	78.93
XII.....	81	11	13.6	67	82.7	64	79.0
XIII-11.....	81	1	1.2	69	85.2	80	98.76
XIV-8.....	81	0	0.0	62	76.5	74	91.35
XIX.....	81	1	1.2	14	17.3	19	23.45
XXIV.....	81	0	0.0	6	7.4	5	6.17
Total.....	4861	55	1.13	1215	24.78	1568	32.05

TABLE X

SUMMARY OF FIELD OBSERVATIONS ON EXPERIMENTAL PLOT, BROESCH FARM, RACINE, WISCONSIN, 1914

Strain	Total no. of plants	July 16		July 30		August 17	
		Number yellow	Per cent yellow	Number yellow	Per cent yellow	Number yellow	Per cent yellow
VIIf (5-7).....	476	7	1.47	158	33.19	262	55.0
VIIi (2-6).....	475	4	0.8	172	36.2	267	56.21
VIIIa (7-35)....	2352	0	0.0	57	2.42	176	7.48
VIIIb (3-18)....	1175	0	0.0	68	5.78	136	11.57
X 135 (8-21)...	1204	0	0.0	315	26.16	594	49.34
X 143 (2-38)...	2379	16	0.67	945	39.72	1477	62.08
XIII 11.....	238	0	0.00	175	73.5	231	97.1
XIV 8.....	236	7	2.87	170	72.0	225	95.8
XV.....	476	137	28.78	448	94.1	454	95.35
XVI.....	479	1	0.2	289	60.3	426	88.9
Total.....	9490	172	1.81	2797	29.47	4248	44.65

A soil thermograph was installed in the experimental plot; the bulb was placed six inches below the surface of the soil, and records were kept covering the growing period. These show that the temperature of the black clay loam, such as is found in Racine and Kenosha counties in Wisconsin, is comparatively high, the minimum temperature of the soil rarely falling below the minimum for the air, and the maximum temperature of the soil, because of the lag, often exceeding that of the air, especially on cold or cloudy days (fig. 15). The same relation between the main attack of the disease and temperature is apparent, although, because the high temperatures were maintained throughout July and August as they had been the previous summer, the percentage of disease also increased over a longer period than in 1912. The total percentage of the disease in this year was less than in the previous years, because plants from the resistant strains were counted with the control, the totals from the entire plot being used.

Experimental results.—The experiments to show the relation between temperature and the attack of the fungus were started in 1913. For this phase of the investigation the plants were grown in uniformly diseased soil in two different greenhouses, one of which was kept as near 25° C. as possible and the other at 15–20° C. In the first experiment three flats of infected soil and one of greenhouse soil (uninfected) were placed in the warm house, and one flat of infected soil and one of uninfected greenhouse soil were placed in the cool house. The flats were planted on October 4, 1913, with two hundred seeds in each flat. The steam was turned on November 18, at which time the plants in all the flats appeared normal in their development. On November 25, however, yellows appeared in the flats of infected soil in the warm house. The plants in uninfected soil in both houses remained healthy. Figures 16–18 give an idea of the range of temperatures in the two houses for the entire period during which these experiments were made.

On December 6 the above experiment was repeated; four flats of infected soil were planted, and two placed in each

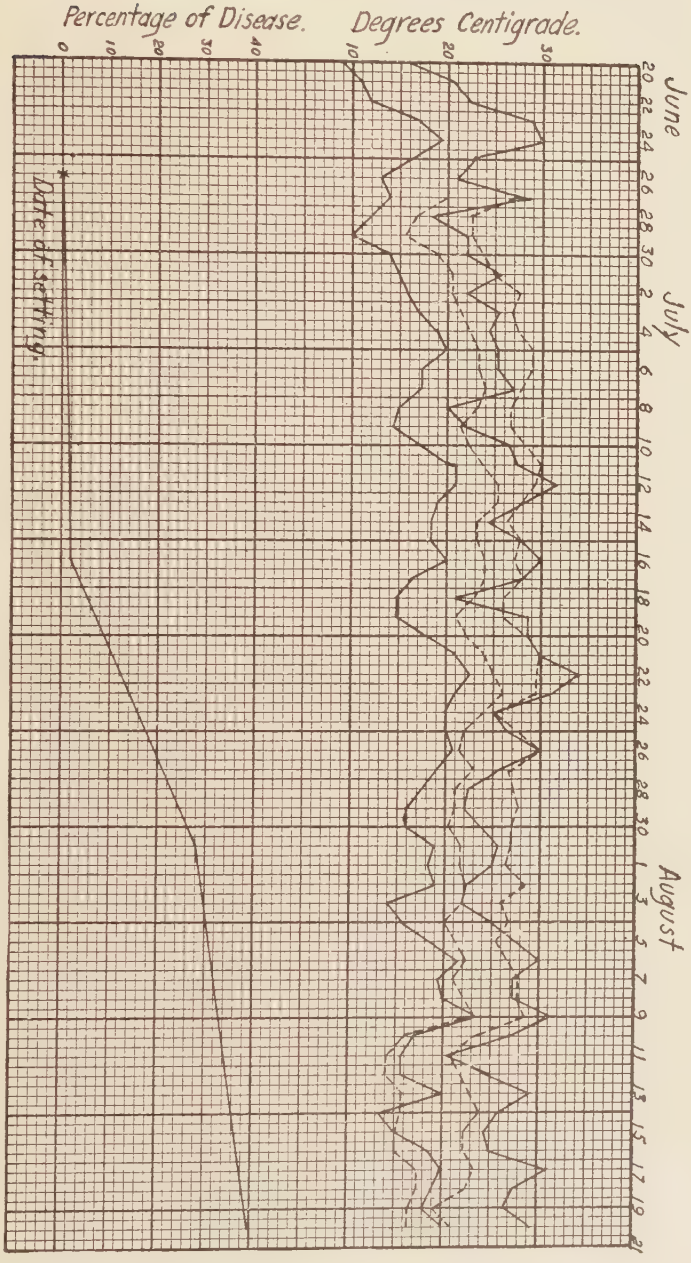


Fig. 15. Comparison of air and soil temperatures with percentage of disease in field in 1914; air temperature, solid line; soil temperature broken line.

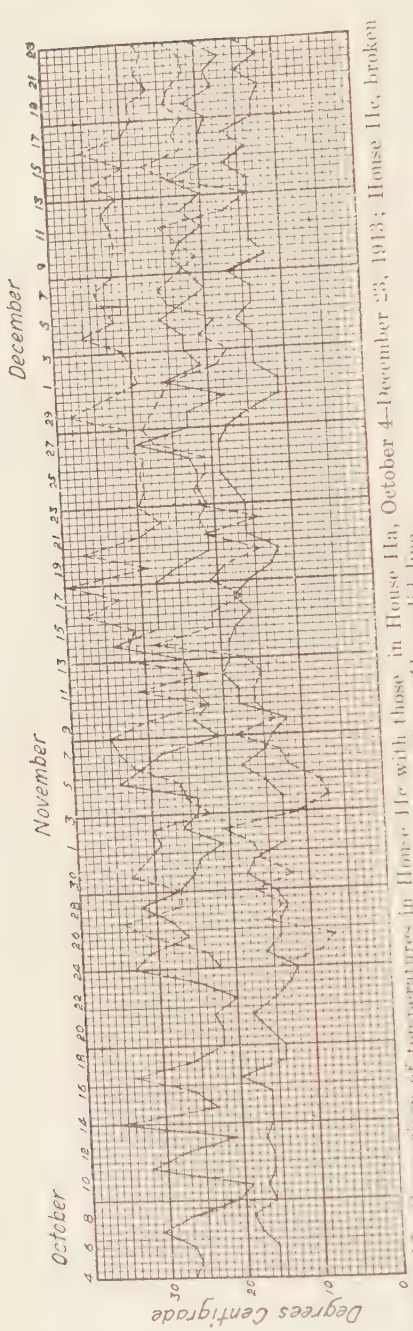


Fig. 16. Comparison of temperatures in House IIe with those in House IIa, October 4–December 23, 1913; House IIe, broken line; House IIa, solid line.

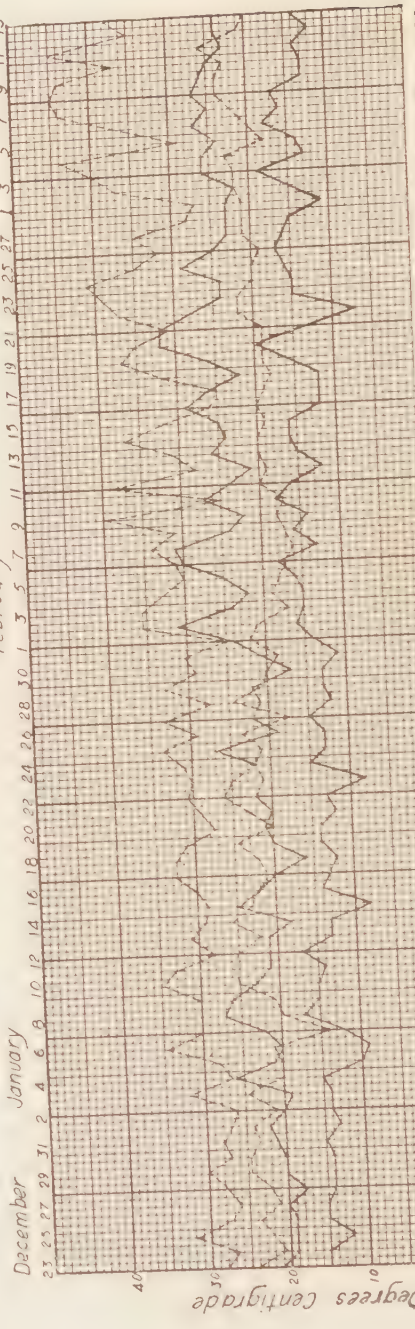


Fig. 17. Comparison of temperatures in House IIe with those in House IIa, December 23, 1913–March 13, 1914; House IIe, broken line; House IIa, solid line.

house. The yellows appeared in the warmer house on December 29. Each of the seedlings showing the symptoms of the disease was sterilized by placing the entire seedling in hydrogen peroxide and washing in sterile water. It was then placed on potato hard agar. The fungus grew readily from the stem of the infected seedlings, as is shown in pl. 2, figs. 8–11. The flats of infected soil were interchanged, and after replanting on January 29, the results were found to be the same; that is, the plants in the warmer house showed the disease, while those in the cooler house remained healthy. The first disease symptoms were observed on February 10.

During the above experiments the temperatures were as constant as they could be made in a greenhouse where the steam supply was regulated by means of an automatic thermoregulator. Of course, the heat on very sunny days was much greater than desired, but this factor could not be controlled, as shading caused too rapid elongation of the plants and a consequent susceptibility to damping off. It was found, however, that the soil temperatures were fairly constant, being from 23 to 26°C. in the warmer house and from 12 to 16°C. in the cooler house. These determinations were made directly by placing the thermometer bulb two inches below the surface of the soil and after the mercury had come to rest making the reading.

In one experiment the number of plants used in the trial was noted, and the percentage diseased after an exposure of three weeks calculated from actual count. The experiment was started January 29, 1914. The trial consisted of seven pots of infected soil, and two pots of normal greenhouse soil for controls. Five pots of infected soil were placed in the warmer greenhouse and two in the cooler house. One pot of the normal greenhouse soil was placed in each house. The disease was found first on February 10, and the plants were pulled and counts made on February 21. If the experiment had been continued, doubtless all the plants in the warmer house would have been destroyed, as they had been in the other experiments. Table XI gives the results.

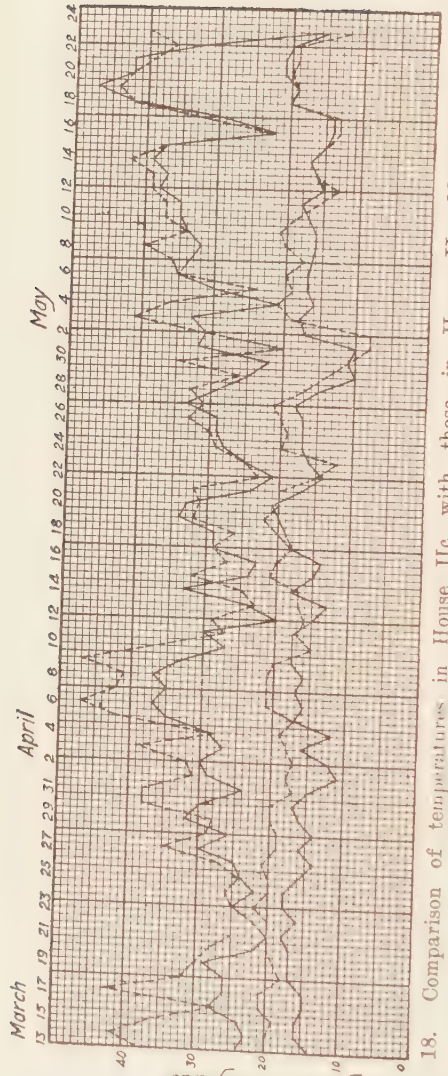


Fig. 18. Comparison of temperatures in House IIe with those in House IIa, March 13–May 23, 1914; House IIe, broken line; House IIa, solid line.

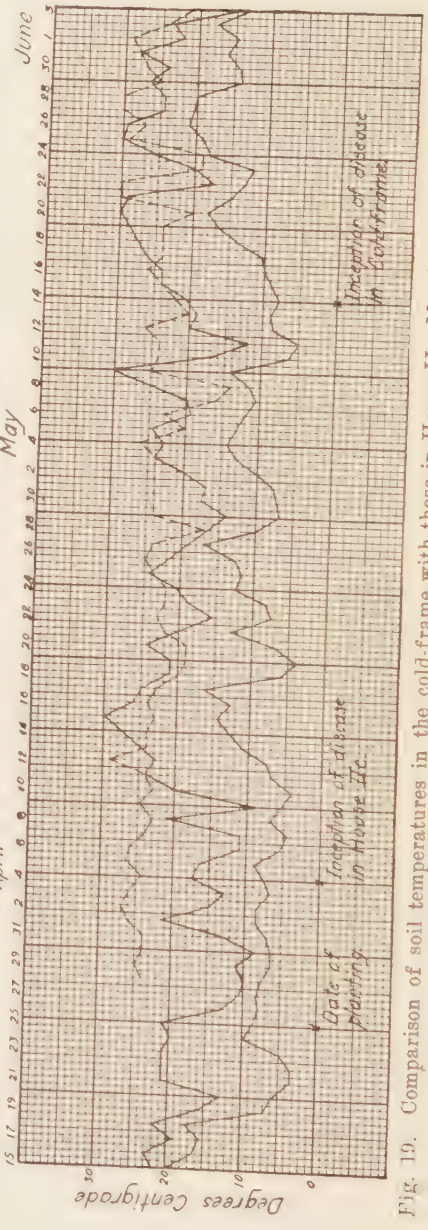


Fig. 19. Comparison of soil temperatures in the cold-frame with those in House IIe, March 15–June 3, 1914; cold-frame, solid line; House IIe, broken line.

TABLE XI

AMOUNT OF YELLOWS PRESENT AFTER AN EXPOSURE OF THREE WEEKS TO HIGH AND LOW TEMPERATURES

Pot no.	Soil	Temperature	Total no. of plants	After three weeks' exposure	
				No. diseased	Per cent diseased
1	Infected	25° C.	73	27	37
2	Infected	25° C.	69	25	38
3	Infected	25° C.	60	16	27
4	Infected	25° C.	54	20	37
5	Infected	25° C.	44	18	41
6	Infected	15–20° C.	60	0	0
7	Infected	15–20° C.	49	0	0
8	Uninfected	25° C.	119	0	0
9	Uninfected	15–20° C.	58	0	0

Again, on February 21, the effect of transplanting normal plants to infected soil at different temperatures was tried. Fifty normal plants were placed in two flats of infected soil

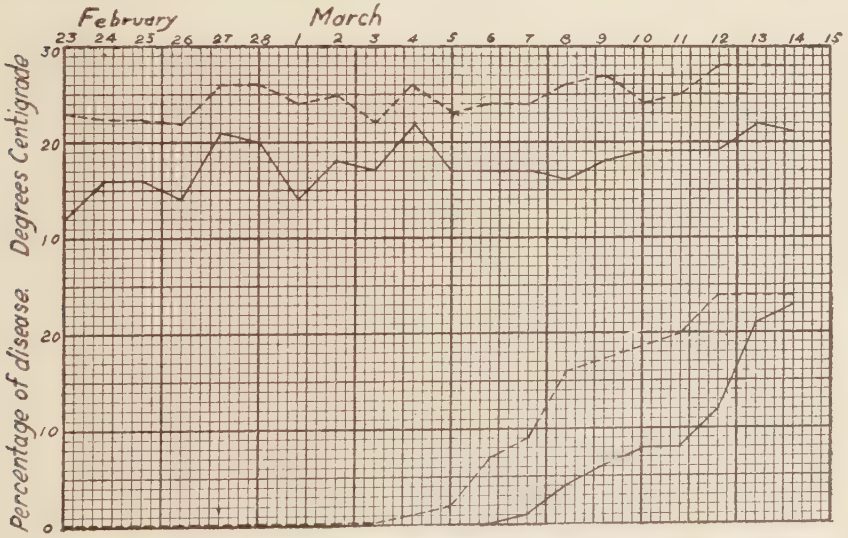


Fig. 20. Comparison of soil temperatures in House IIc and those in House IIa with the occurrence of yellows in the respective houses; House IIc, broken line; House IIa, solid line.

and one flat placed in each house. Controls consisted of ten normal plants from the same flat as the above, placed in normal greenhouse soil in two pots, one pot in each house. Soil

temperatures were taken daily. The results are not conclusive, as the temperature in the cooler house rose to 21°C. on the sixth day and remained high for two days, nor did it go back to below the temperature at which infection took place. Nevertheless, the symptoms appeared in the warmer house March 4, three days before the plants in the cool house showed any sign of the trouble, and the cooler soil retarded the advance of the fungus proportionately, as may be seen from the curves (fig. 20).

In further experiments on this temperature relation a cold-frame was used as a means of maintaining cooler conditions, for the greenhouses were all too warm, due to the increased intensity of sunlight, especially at midday. The north side of the potting-house, where the sun was excluded, made it possible to carry these cultures still further into the spring, and in all cases the results were the same.

In the experiment in which the cold-frame was used, a soil thermograph of the type manufactured by Julien P. Friez was installed. The bulb was imbedded four inches in the soil, and the temperature of the soil and air were recorded throughout the experiment. The plants were started on March 25 in six flats of uniformly infected soil, three of which were placed in the greenhouse at 25° C. and three in the cold-frame. Two pots of greenhouse soil, planted to cabbage, were used as controls in each case. The disease appeared first in the greenhouse on April 4, ten days after planting. Seedlings were plated from the diseased flats and from the flats in the cold-frame on April 9, and in all cases the diseased seedlings showed the fungus growing from the stem, while the controls remained sterile. On April 13, photographs were made of two of the flats—one from the cold-frame showing the healthy condition of the seedlings, and one from the greenhouse showing the ravages due to the attack of the fungus (pl. 2, fig. 7). The temperature records show that there was an increase in temperature with the advance of the season, and it was due to this increase in temperature that the attack occurred. The curves (fig. 19) do not show this fact well, as they are a record of the maximum and minimum only and do

not show the duration of temperature in any one day. The records themselves, while they cannot be presented here, show this increase more markedly—for the length of time of the higher temperatures increased—as the spring gave way to summer conditions. In any case the cooler condition prevented the attack of the fungus for at least a month.

In the experiment in which the flats were placed on the north side of the potting-shed, three flats of diseased soil were used. Two were placed on the north side of the potting-shed, and the third in the warm house. The flats were planted April 9, and yellows appeared in the flat in the greenhouse on April 17, while none was found, up to May 26, in the flats kept outside. Soil temperatures covering this period are shown by the curves in fig. 21.

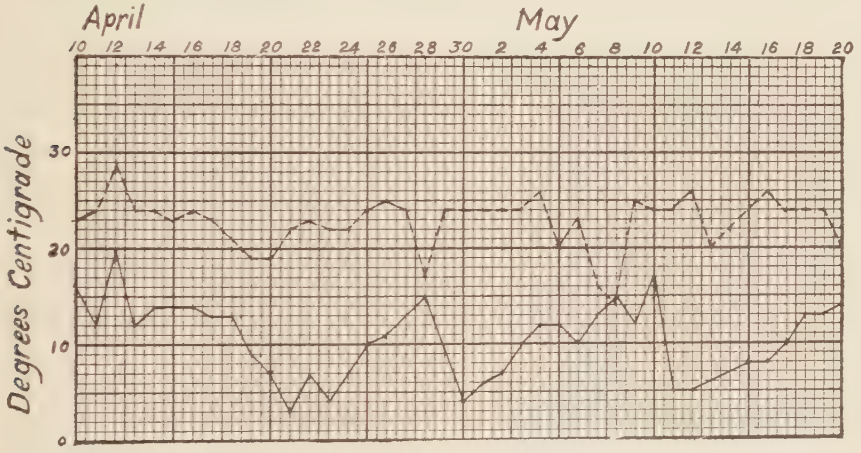


Fig. 21. Comparison of soil temperatures in House IIc with those on north side of potting-shed, April 10–May 20, 1914; House IIc, broken line; north side of potting-shed, solid line.

Further work was undertaken at the Missouri Botanical Garden to try to determine the lowest point at which the attack may occur. To this end two glass incubators were set up, and the temperature was controlled by an electric thermoregulator, so that it varied but a degree or two at the most. One incubator was set up in the laboratory at a west window, and the other was placed on the north side of the building. The temperature of the incubator in the laboratory was kept

at 22–24°C., this being the lowest constant temperature that could be procured in the room. The incubator outside was set at 16°C., but on account of the wide variation in atmospheric temperatures it was not possible to keep it constant at this point. At times the temperatures reached as high as 21°C., and at other times as low as 10°C. In spite of this variation no yellows occurred in the incubator which was outside until some days after all the plants in the warmer incubator had been attacked. Twenty pots of soil from the experimental field at Racine were placed in the warm incubator and twenty similar pots were placed in the cool incubator. The pots were put in the incubators on November 5, 1914, and in four days the plants in one pot showed wilting. The plants were sixteen days old when they were submitted to the trial. Previous to this time they had been growing in the greenhouse which was kept at 12–14°C. On November 11 yellowing was apparent in all the pots except the controls, some of the plants also showing wilting. In the outside incubator but two plants showed a slight yellowing and there was no wilting. Damping off due to *Rhizoctonia* was rather extensive in some of the pots because of the relatively high humidity conditions. Counts were taken on November 14 of the plants in the warm incubator, and seedlings from both incubators were plated on potato hard agar. The results were as follows:

At 22–24°C. *F. conglutinans* was isolated from plants from every pot of the infected soil, while none could be isolated from the plants in the normal greenhouse soil. When the plants from eight pots of infected soil, growing at 10–16°C., were plated *F. conglutinans* was isolated from but one; the fungus was not isolated from the controls. In the twenty pots at 22–24° C. there was a total of 104 plants, seven of which remained healthy, while in the incubator at 10–16° C. there was a total of eighty-eight plants, only one of which showed the disease even after they had been left until December 1 in the incubator. Table xii summarizes the results obtained on this temperature relation.

TABLE XII

SUMMARY OF RESULTS OF EXPERIMENTS TO SHOW THE RELATION OF TEMPERATURE TO ATTACK OF THE FUNGUS

Incubation period in days	Extent of trial				Approximate average temperature in °C.		Condition of control at inception of disease
	Infected soil		Uninfected soil				
	Higher temperature	Lower temperature	Higher temperature	Lower temperature	Higher	Lower	
13	3 flats.	1 flat..	1 flat..	1 flat..	22°	16–20°	Healthy..
21	1 flat..	1 flat..	1 pot..	1 pot..	22°	16–20°	Healthy*.
30	10 pots.	12 pots.	1 pot..	1 pot..	22°	14–16°	Healthy..
4	20 pots.	20 pots.	3 pots.	3 pots.	22–24°	10–16°	Healthy*.
23	3 flats.	1 flat..	1 flat..	1 flat..	25°	14–18°	Healthy..
12	3 flats.	1 flat..	1 flat..	1 flat..	25°	14–18°	Healthy..
12	7 pots.	5 pots.	2 pots.	2 pots.	25°	14–18°	Healthy..
8	2 flats.	1 flat..	2 pots.	2 pots.	25°	14–16°	Healthy..
10	3 flats.	3 flats.	2 pots.	2 pots.	30°	14–16°	Healthy*.

*In these cases the controls in infected soil at the lower temperatures became diseased later, due to a rise of temperature above the point at which they were able to resist the disease.

In a further experiment seeds were planted on October 20 in pots of infected soil and allowed to stay in the greenhouse. The soil temperature was 10–16°C., and while a little disease appeared from time to time after December 1, 1914, the attack was very light and very few of the plants suffered. When on February 2, five pots of these plants were taken to a greenhouse whose air temperature was 28–30°C., yellows appeared in virulent form in three days and all but three plants were dead on February 20. Plate 1, fig. 3, shows typical pots from this experiment. It was repeated February 28 with similar results.

The fact that high temperatures caused the yellowing of the cabbage when the plant was attacked by *F. conglutinans* having been clearly established, the next point was to find, if possible, whether the fungus entered the host at the lower temperature or not. The first experiments were made by plating from the plants in the lower temperatures, especially from parts of the roots of plants grown in infected soil. Although the plates were made in the same manner and with the same

care as in the case of the yellowed seedlings grown at higher temperatures, at no time was *F. conglutinans* isolated from the roots of these plants. Controls from roots grown at the higher temperatures showed the fungus, as has been pointed out in previous experiments. Experiments were therefore instituted to test whether any such relation might be indicated by indirect methods.

The first experiment was started on April 21, 1914, at which time twenty pots of infected soil were planted to cabbage, and all were placed on the north side of the potting-shed where a low temperature could be maintained. They were kept here until June 6, sixteen days, when all but two were placed in House IIc which was being kept at approximately 25°C. On June 9, after the pots had remained in the warm house for three days, pairs of pots were removed to the cooler temperature at intervals of two days until June 15, after which date a pair was removed each day until June 19. On June 30 yellows appeared in the two pots removed on the last day, June 19, but none was found in any of the other pots. This experiment showed that in this case the yellows appeared in the same length of time as it usually took to appear in a warm house, and would lead to the opinion that there had been no infection at the low temperature, or if the plants had been attacked, that they were able to recover under favorable conditions for growth.

Coincident with this last experiment, moreover, twenty pots of infected soil planted to cabbage were placed in House IIc, and each day two pots were removed to the cooler temperature. No yellows appeared in any pots removed in the first eight days, but in all those removed subsequently yellowing was found on June 2. Controls in the warm house showed the first symptoms on June 1, one day earlier than those on the outside. The cooler temperature, therefore, checked the disease in most cases, but where it had gone too far, the only effect was a slight lengthening of the period of incubation.

Later observations on this point do not seem to confirm these results. It will be noted that in the experiments carried on at the Missouri Botanical Garden, when the plants

were first grown in the greenhouse and then placed in the incubator at 22–24°C., the disease appeared in but four days, a period that was shorter than had been noted in any other experiment. This trial was repeated on March 9, and again the seedlings showed the disease in four days, on March 13. Eight pots of seedlings were used, and the disease appeared in all the pots on the same day, although not all the seedlings in any one pot were yellow at this time. Previous to the appearance of the yellows, platings made from the roots by the hydrogen-peroxide method gave negative results in all cases. Further, the roots were washed out of the soil and examined carefully under the microscope, but no hyphae of the fungus were observed until after wilting or yellowing had begun. The rotting usually began at the tips of roots near the surface of the soil, and progressed toward the main roots and stem. The only explanation that seems applicable to these conflicting results is that, because the temperature in the greenhouse at the Garden is slightly higher than that found on the outside of the potting-shed, the fungus may enter to a limited extent, but cannot affect the host unfavorably except at the higher temperature, while at Madison it was unable to gain any sort of a foothold. This view is further supported by the fact that a few plants grown in diseased soil in this greenhouse, after a long period of time showed yellows, as previously mentioned.

Because the small number of hyphae found in any single diseased stem seemed insufficient for the blocking of the passage of water to the leaves of the diseased plant, some preliminary work was undertaken to find, if possible, whether mechanical or chemical killing of the stem might bring about symptoms in the leaves similar to those produced by the fungus, and especially with regard to the production of a toxic substance to which the symptoms might be ascribed.

To test this question six plants of cabbage were cut on one side with a scalpel so that half of the stem was removed for a distance of 0.5 cm. The plants were about two weeks old and growing rapidly. The cut surfaces were covered with paraffin to prevent too rapid drying of the tender tissues. Two

plants showed wilting in nine days but the others all remained upright and turgid, having completely recovered. There was no discoloration of the leaves in connection with the wilting.

In a later experiment with older plants, the entire stem of each plant was killed for a distance of 3 cm. from the surface of the ground by allowing it to stand in alcohol for three minutes. After nine days, wilting appeared in one of the five plants, the lowest leaves drooping first, but with no discoloration such as occurs under the influence of fungous attack, nor falling of the wilted leaves. A second plant succumbed on the twelfth day, but again there was rapid wilting with no loss of green coloring matter. By the eighteenth day all the plants had wilted, but even where the injury had been least and the wilting slowest there was no discoloration or falling of the leaves. The experiment was repeated with older plants in March, 1915, with similar results. The wilting always took place without discoloration of the leaves, nor did any of them drop before the entire head was wilted.

Further work was started, therefore, to see whether the fungus could produce in pure culture any substances toxic to cabbage. For this study two Erlenmeyer flasks of half-liter capacity, each containing 100 cc. of Uschinsky's fluid, were inoculated with a virulent culture of *F. conglutinans*. After two weeks the fungus-felt was filtered from the solution by means of a pressure filter, and the solution, after dilution to 500 cc., was poured in two glass tumblers, in which germinated cabbage seedlings were then placed. Controls of Uschinsky's fluid diluted 2:5, tap water, and Pfeffer's full nutrient were used in connection with the experiment. Difficulty was experienced in getting the plants to start because of the desiccation of the young cotyledons. By placing the plants in an incubator under humid conditions, the plants growing on tap water and Pfeffer's solution grew fairly well, but on Uschinsky's fluid, neither on that in which the fungus had been growing nor on the sterile fluid, was it possible to get any growth, indicating that some other media or methods will have to be used. Further work on this point is being pursued.

Discussion.—Exactly why the raising of the temperature should bring on this disease is still not clear, but in view of our present knowledge some correlation should be made between the relations found and the other work that may shed light on this point. First, it should be pointed out that many of the so-called vascular parasites behave in a very similar manner toward temperature. As Smith ('14) has shown with *Bacillus Solanacearum*, Humphrey ('14) with *Fusarium orthoceras*, and the present investigation with *F. conglutinans*, high temperatures facilitate the destruction of the host. To what extent this destructiveness may be attributed to changes in the parasite and to what extent to changes in the host plant, it is difficult to determine. Smith and Humphrey both are inclined to consider the changes in the host the primary factors concerned, and as will be pointed out, the same opinion may be taken in the case of the cabbage disease. Nevertheless, the change in the fungus must be looked into also.

Among diseases of plants that are partially dependent on temperature relations for their occurrence, in many of the cases the relation is not one of loss of virulence on the part of the fungus but a limitation in the temperature range of germination of the fungous spores. This sort of limitation was best illustrated by the work of Melhus ('12, '13) on *Phytophthora infestans* as related to the potato blight. This author showed that, although the spores germinated only at low temperatures, the mycelium which wintered over in the tuber, attacked the new shoots from such tubers only at high temperatures. Other cases of similar nature, where the temperature for spore germination differed from that of mycelial growth, are found among many of the obligate plant parasites. Examples that might be cited are *Cystopus candidus, Plasmopara Viticola, Ustilago Avenae, U. Tritici, Uromyces Trifolii, Peridermium Strobi, Puccinia graminis, P. rubigo-vera, P. dispersa,* and *P. coronata.*

That *Fusarium conglutinans* is not dependent on germination temperatures for its destructive attack is clearly shown by the fact that germination occurs readily at 17°C., which temperature is close to the lower limits of its destructiveness

in the case of cabbage. Moreover, it grows readily at temperatures much lower than this. The raising of the temperature merely increases the rapidity of the growth of the fungus and, therefore, as far as this investigation is concerned, the high temperature from the standpoint of the fungus aids its destructiveness by increased spread in the soil, and more rapid development in the vascular system after it has once entered. Other possible relations, such as that of production of toxic substances, remain to be worked out.

From the host standpoint the effect of temperature is much more complicated. Appel ('15) in his discussion of leaf roll in potato considered excessive transpiration of prime importance in bringing about this condition whether the cause of the trouble was parasitic or not. The symptoms of the disease in the cabbage indicate that the phenomena involved are very similar to those concerned with the annual autumn fall of leaves from woody plants. The discoloration (yellowing in the diseased plants), the formation of an abscission layer, and finally the fall of the leaves are in all ways comparable. Hence the same physiological changes within the plant are probably taking place. From this point of view then, the work of Molisch ('86) and Varga ('11) on the relations of environmental factors to the fall of leaves gives a basis for an explanation of the symptoms from the host standpoint. Molisch showed that a slow but continued decrease of water content of the fundamental tissue of the leaf led to the formation of an abscission layer and finally fall of the leaf. He further found that this loss of water might be brought about by increased transpiration or by decreased absorption or conduction from the roots to the leaf. Temperature influenced leaf-fall, both indirectly through its effect on transpiration, and directly by bringing about the formation of the abscission layer. Leaves fell at 17–22°C. more rapidly than at 1–10°C. when other conditions were equal. Varga studied the relation of temperature to leaf fall more exactly and found that, as a rule, low temperatures lowered transpiration and thereby set up a stimulus to leaf fall, but that if the abscission layer had been formed through other influences, higher tempera-

tures within limits, caused a more rapid fall of the leaves. These facts give a possible explanation of the results found with cabbage yellows. The hyphae of *F. conglutinans* in the fibro-vascular bundles cause a constant but slow drain on the water content of the plant, which causes the formation or the beginning, at least, of the formation, of the abscission layer. High temperatures, in addition to causing increased growth of the fungus, raise the transpiration and also stimulate leaf-fall; thus all the factors are cumulative in their effect.

The reason that mechanical and chemical injuries to the stem did not cause similar symptoms may be explained by the fact that the plants wilted before sufficient time was given for the formation of the abscission layer and, therefore, the difference in symptoms. This theory also concurs with that of Humphrey in regard to the tomato blight, but a large amount of work is still necessary before it will be completely proven.

Summary

Cabbage yellows is a wilt disease of cabbage caused by *Fusarium conglutinans* Wollenw.

The fungus is a facultative parasite living in the soil, from which, under certain conditions, it becomes destructive to cabbage.

The fungus has a high optimum temperature and is very resistant to drying—both in pure culture and in the soil.

Inoculation experiments with *Fusarium conglutinans* in pure culture caused the disease in a large percentage of the trials. Control plants remained entirely free from the yellows. *Fusarium conglutinans* was recovered from inoculated diseased seedlings and again produced the disease upon inoculation.

Variation in virulence of the cultures and in susceptibility of the host caused many artificial inoculations to be unsuccessful, resulting in less than 100 per cent infection.

Mechanical or chemical injury to the stem of the host caused wilting, but neither yellowing nor dropping of the leaves such as is found in diseased seedlings.

The characteristic symptoms are dependent on a temperature of about 17–22°C. or above for their occurrence. Lower temperatures (12–16°C.) under controlled conditions prevented the occurrence of the trouble in the greenhouse.

Observations made in the field during the summers of 1912, 1913, and 1914 bore out this relation between the occurrence of the disease and high temperature.

In conclusion, the writer wishes to express to Dr. L. R. Jones, at whose suggestion this investigation was undertaken, and to Dr. B. M. Duggar, under whom it was completed, his sincere appreciation of the many valuable suggestions and helpful criticisms given during the progress of this work. He is further indebted to the support of the Wisconsin Experiment Station for the opportunity of conducting the initial stages of the work and to the Missouri Botanical Garden for the completion of the work upon the problem.

Graduate Laboratory, Missouri Botanical Garden.

Literature Cited

Appel, O. ('15). Leaf roll diseases of the potato. Phytopath. 5:139–148. 1915.

———, und Wollenweber, H. W. ('10). Grundlagen einer Monographie der Gattung Fusarium (Link). K. biol. Anst. f. Land- u. Forstw., Arb. 8:1–207. *pl. 1–3. f. 10.* 1910.

Atkinson, G. F. ('95). Damping off. Cornell Univ. Agr. Exp. Sta., Bul. 94:233–272. *pl. 1–6. f. 55.* 1895.

Bakke, G. L. ('12). The late blight of barley (Helminthosporium teres Sacc.). Ia. Acad. Sci., Proc. 19:93–102. *pl. 1–3.* 1912.

Balls, W. L. ('08). Temperature and growth. Ann. Bot. 22:557–591. *f. 1–4.* 1908.

Brefeld, O. ('95). Untersuchungen aus dem Gesamtgebiete der Mykologie 11:27–28. 1895.

De Thümen, ('80). Hedwigia 19: p. 191. 1880.

Duggar, B. M. ('09). The effects of conditions of growth upon susceptibility to fungous diseases. Mass. Hort. Soc., Trans. 1909:51–66. 1909.

Earle, F. S. ('02). Health and disease in plants. N. Y. Bot. Gard., Jour. 3:195–202. *f. 26.* 1902.

Edgerton, C. W. ('15). Effect of temperature on Glomerella. (Science N. S. 41:174. 1915).

Edson, A. W. ('03). The black rot of grapes in North Carolina. N. C. Agr Exp. Sta., Bul. 185:133–156. 1903.

Eriksson, J. ('95). Ueber die Förderung der Pilzsporenkeimung durch Kälte. Centralbl. f. Bakt. II. 1:557–565. *1 f.* 1895.

Falck, R. ('07). Wachstumsgesetze, Wachstumsfaktoren und Temperaturwerte der holzzerstörenden Mycelien. Möller's Hausschwamm-forschungen. Heft 1:53–152. 1907.

Gifford, C. M. ('11). The damping off of coniferous seedlings. Vt. Agr. Exp. Sta., Bul. 157:143–171. *pl. 1–4. f. 1–10.* 1911.

Gilman, J. C. ('14). The relation of temperature to the infection of cabbage by Fusarium conglutinans Wollenw. (Phytopath. 4:404. 1914).

Halsted, B. D. ('98). Influence of wet weather upon parasitic fungi. (Am. Assoc. Adv. Sci., Proc. 47:416. 1898).

Harter, L. L. ('09). Fusarium wilt of cabbage. Science N. S. 30:934. 1909.

————, ('12). Diseases of cabbage and related crops and their control. U. S. Dept. Agr., Farmers' Bul. 488:18–21. *f. 4.* 1912.

Hecke, L. ('09). Der Einfluss von Sorte und Temperatur auf dem Steinbrandbefall. Zeitschr. f. Landw. Versuchsw. Österr. 12:46–66. 1909.

Howell, J. K. ('90). The clover rust. Cornell Univ. Agr. Exp. Sta., Bul. 24:129–139. *f. 1–8.* 1890.

Humphrey, H. B. ('14). Studies on the relation of certain species of Fusarium to the tomato blight of the Pacific Northwest. Wash. Agr. Exp. Sta., Bul. 115:1–22. *pl. 1–4.* 1914.

Istvánffi, G. and Pálinkás, G. ('13). Études sur le mildiou de la vigne. Ann. l'Inst. Cent. Ampelol. Roy. Hongrois. 4:1–125. *pl. 9. f. 1.* 1913.

Johnson, E. C. ('12). Cardinal temperatures for the germinating of uredospores of cereal rusts. (Phytopath. 2:47–48. 1912).

Johnson, J. ('14). The control of damping-off disease in plant beds. Wis. Agr. Exp. Sta., Res. Bul. 31:29–61. *f. 1–12.* 1914.

Jones, L. R. ('08). The damping off of coniferous seedlings. Vt. Agr. Exp. Sta., Rept. 20:342–347. 1908.

————, ('13). The possibilities of disease resistance in cabbage. (Phytopath. 3:71. 1913).

————, ('14). Progress in developing disease-resistant cabbage. (*Ibid.* 4:47–48. 1914).

————, ('14[a]). Third progress report on Fusarium-resistant cabbage. (*Ibid.* 4:404. 1914).

————, and Gilman, J. C. ('15). The control of cabbage yellows through disease resistance. Wis. Agr. Exp. Sta., Res. Bul. 38:1–70. *f. 1–17.* 1915.

Klebahn, H. ('12). Grundzüge der allgemeinen Phytopathologie. pp. 1–147. *f. 1–74.* Berlin, 1912.

Lewis, C. E. ('13). Comparative studies of certain disease producing species of Fusarium. Me. Agr. Exp. Sta., Bul. 219:203–258. *f. 89–118.* 1913.

Lutman, B. F. ('11). Potato diseases and the weather. Vt. Agr. Exp. Sta., Bul. 159:248–296. 1911.

Manns, T. F. ('11). Two recent important cabbage diseases of Ohio. Ohio Agr. Exp. Sta., Bul. 228:262–275. *f. 2–14.* 1911.

Melhus, I. E. ('11). Experiments on spore germination and infection in certain species of Oomycetes. Wis. Agr. Exp. Sta., Res. Bul. 15:25–91. *pl. 1–10.* 1911.

————, ('12). The factors governing germination and infection with Phytophthora infestans. (Phytopath. 2:46. 1912).

————, ('13). Resting mycelia of Phytophthora and other related species. (*Ibid.* 3:70. 1913).

Molisch, H. ('86). Untersuchungen über Laubfall. Sitzungsber. d. k. Akad. d. Wiss., Wien 93[1]:148–184. 1886.

Munerati, O. ('12). Sulla recettività del frumento per la carie in rapporto al tempo di semina. Atti. r. Accad. Lincei, Rendic. 21[2]:875–878. 1912.

Norton, J. B. S., and Symons, T. B. ('07). Control of insect pests and diseases of Maryland crops. Md. Agr. Exp. Sta., Bul. 115:184. 1907.

Orton, W. A. ('13). Environmental influences in the pathology of Solanum tuberosum. Washington Acad. Sci., Jour. 3:180–190. *f. 1–3.* 1913.

———, ('14). Potato wilt, leaf-roll, and related diseases. U. S. Dept. Agr., Bul. 64:1–16. *pl. 1–2.* 1914.

Petri, L. ('13). Disseccamento dei rametti di Pseudotsuga Douglasii Carr. prodotto da una varietà di Sphaeropsis Ellisii Sacc. Ann. Myc. 11:278–280. 1913.

Pierce, N. B. ('00). Peach leaf curl: its nature and treatment. U. S. Dept. Agr., Div. Veg. Phys. and Path., Bul. 20:22–30. 1900.

Ravaz, L., and Verge, G. ('12). Conditions de développement du mildiou. Prog. Agr. et Vit. 55:485–488. 1912.

———, ———, ('12a). Influence de la température sur la germination des conidies du mildiou. *Ibid.* 55:170–177. 1912.

———, ———, ('12b). Sur les conditions d'apparition des conidiophores du mildiou. *Ibid.* 55:296–300. 1912.

Ravn, F. K. ('00). Nogle Helminthosporium-Arten og de af dem fremkaldte Sygdomme hos Byg og Havre. Bot. Tidsskr. 23:101–321. *pl. 1–2. f. 1–26.* 1900.

Reed, G. M. ('10). The influence of environmental conditions upon the development of plant diseases. Mo. State Bd. Hort., Bul. 31:1–14. 1910.

Reed, H. S. ('12). Does Phytophthora infestans cause tomato blight? Phytopath. 2:250–252. 1912.

Sajó, K. ('01). Meteorologische Ansprüche von Oidium Tuckeri und Peronospora viticola. Zeitschr. Pflanzenkr. 11:92–95. 1901.

———, ('02). Verschiedene meteorologische Ansprüche der schädlichen Pilze. Prometheus 13:132–135, 154–157. 1902.

Salmon, E. S. ('00). The strawberry mildew. Roy. Hort. Soc., Jour. 25:132–138. *f. 35–36.* 1900.

Schuster, J. ('12). Zur Kenntnis der Bakterienfäule der Kartoffel. K. biol. Anst. f. Land- u. Forstw., Arb. 8:452–492. *pl. 5. f. 1–13.* 1912.

Scott, W. M. ('06). The control of apple bitter-rot. U. S. Dept. Agr., Bur. Pl. Ind., Bul. 93:1–33. *pl. 1–8. f. 1.* 1906.

Selby, A. D. ('99). Variations in the amount of leaf curl of the peach (Exoascus deformans) in the light of weather conditions. Soc. Prom. Agr. Sci., Proc. 20:98–104. 1899.

———, ('04.) Peach diseases III. Ohio Agr. Exp. Sta., Bul. 148:57–58. 1904.

Smith, E. F. ('99). The fungous infestation of agricultural soils in the United States. Scientif. American, Suppl. 48:19981. 1899.

———, ('99a). A wilt disease of cotton, watermelon and cowpea. U. S. Dept. Agr., Div. Veg. Phys. and Path., Bul. 17:41–42. 1899.

———, ('14). Bacteria in relation to plant diseases. Carnegie Inst. Washington Publ. 27[3]:174–206. 1914.

Stevens, F. L. ('13). The fungi which cause plant disease. p. 654. New York, 1913.

Tubeuf, C. F. von ('01). Studien über die Brandkrankheiten des Getreides und ihre Bekämpfung. K. biol. Abt. f. Land- u. Forstw., Arb. 2:179–349. *pl. 8, f. 1–19.* 1901.

Van Hook, J. M. ('04). Diseases of ginseng. Cornell Univ. Agr. Exp. Sta., Bul. 219:181–182. *f. 39–41.* 1904.

Varga, O. ('11). Beiträge zur Kenntnis der Beziehungen des Lichtes und der Temperatur zum Laubfall. Oesterr. Bot. Zeitschr. 61:74–88. 1911.

Vaughan, R. E. ('14). A method for the differential staining of fungous and host cells. Ann. Mo. Bot. Gard. 1:241–242. 1914.

Viala, P. ('87). Les maladies de la vigne. pp. 245–270. Paris, 1887.

Ward, M. ('01). The bromes and their brome rust. Brit. Assoc. Adv. Sci., Rept. 71:836–839. 1901.

Whetzel, H. H. ('06). The blight canker of apple-trees. Cornell Univ. Agr. Exp. Sta., Bul. 236:103–138. *f. 49–84.* 1906.

Wolf, F. A. ('10). A Fusarium disease of the pansy. Mycologia 2:19–22. 1910.

Wollenweber, H. W. ('13). Pilzparasitäre Welkekrankheiten der Kulturpflanzen. Ber. d. deut. bot. Ges. 31:17–34. 1913.

————, ('13a). Studies on the Fusarium problem. Phytopath. 3:24–50. *pl. 5. f. 1.* 1913.

Woods, A. F. ('99). The destruction of chlorophyll by oxidizing enzymes. Centralbl. f. Bakt. II. 5:745–754. 1899.

Explanation of Plate

PLATE 1

Fig. 1. Results of inoculation in the greenhouse with pure cultures.
Pot No. 1. Infected soil, sterilized.
Pot No. 2. Sterilized soil inoculated with pure culture of *F. conglutinans*.
Pot No. 3. Soil from infected field, untreated.
Madison, Wisconsin, July 14, 1913.
Fig. 2. Results of inoculation in the garden with pure cultures.
Pot No. 1. Infected soil, sterilized.
Pot No. 2. Sterilized soil inoculated with pure culture of *F. conglutinans*.
Pot No. 3. Soil from infected field, untreated.
Madison, Wisconsin, July 14, 1913.
Fig. 3. Effect of temperature on the attack of *F. conglutinans* on cabbage.
Pot No. 1. Uninfected soil in cool house.
Pot No. 2. Infected soil in cool house.
Pot No. 3. Infected soil in warm house.
Pot No. 4. Uninfected soil in warm house.
Missouri Botanical Garden, March 1, 1915.
Fig. 4. Diseased cabbage plant showing typical one-sided bending of leaf and loss of lower leaves. Madison, Wisconsin.

Fig. 1

Fig. 2

Fig. 4

Fig. 3

GILMAN—CABBAGE YELLOWS

Explanation of Plate

PLATE 2

Figs. 5 and 6. Comparison of rate of germination of resistant and commercial varieties of cabbage under the same conditions. Fig. 5, commercial sort; fig. 6, resistant. Missouri Botanical Garden, November 5, 1914.

Fig. 7. Effect of temperature on the attack of *F. conglutinans* on cabbage. On left, flat from cold-frame; on right, flat from House IIc. Madison, Wisconsin, April 13, 1914.

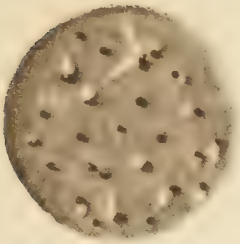
Figs. 8, 9, 10, and 11. Effect of temperature on the attack of *F. conglutinans* on cabbage. Fig. 8, plants from temperature control in cold-frame; fig. 9, plants from soil control in House IIc; fig. 10, plants from Flat No. 1 in House IIc; fig. 11, plants from Flat No. II in House IIc. Flats Nos. I and II and the temperature control all contained infected soil. Soil control was uninfected greenhouse soil. Madison, Wisconsin, April 11, 1914.

Fig. 12. Branched cabbage plant, one branch, *DE*, showing yellows, while other, *BC*, remains healthy. Platings made from marked points and results shown in fig. 13. Madison, Wisconsin, May 19, 1914.

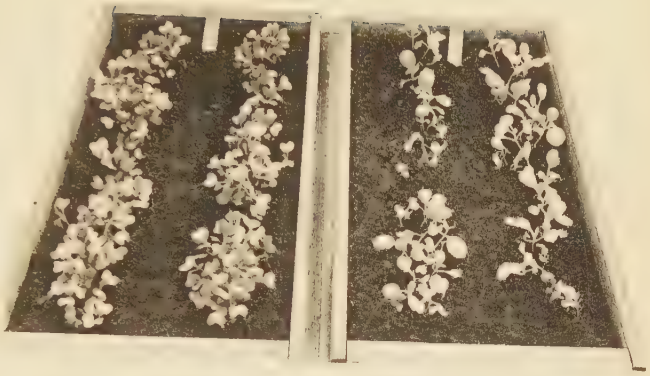
Fig. 13. Plate made from plant shown in fig. 12. Note that pieces *B* and *C* from healthy branch remained sterile. Madison, Wisconsin, May 21, 1914.

Fig. 14. Stems of infected cabbage plant on potato hard agar. Note mycelial growth from vascular bundles and ends of cut stem. Madison, Wisconsin.

Figs. 15 and 16. Comparison of results of inoculation experiment. Fig. 15 shows three pieces of stem from each of three healthy cabbage plants grown in sterilized soil; fig. 16 shows the same from three diseased plants grown in soil that had been sterilized and inoculated with pure culture of *F. conglutinans*. Madison, Wisconsin, July 16, 1913.

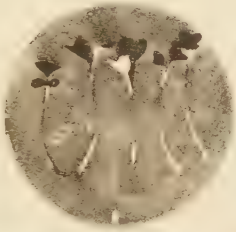


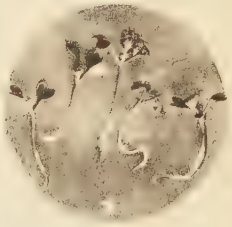
5



7

6

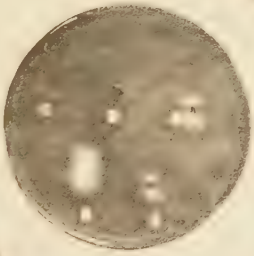




9

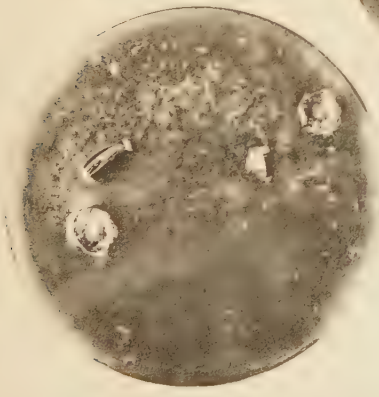
12

10

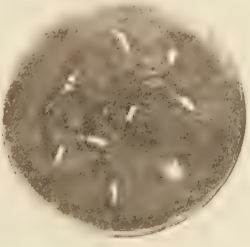


13

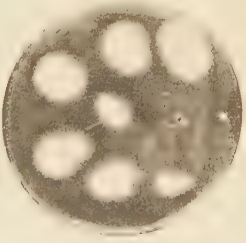
11



14



15



16

GILMAN—CABBAGE YELLOWS

MONOGRAPH OF THE NORTH AND CENTRAL AMERICAN SPECIES OF THE GENUS SENECIO—PART II[1]

J. M. GREENMAN

Curator of the Herbarium of the Missouri Botanical Garden
Associate Professor in the Henry Shaw School of Botany of Washington University

Sect. 6. Aurei Rydb.

§ 6. Aurei Rydb. Bull. Torr. Bot. Club **27**:173. 1900; Greenm. Monogr. Senecio, I. Teil, 22, 23, 29, 30. 1901, and in Engl. Bot. Jahrb. **32**:18, 19, 25, 26. 1902.

Herbaceous perennials, glabrous or in the early stages floccose-tomentose and more or less glabrate except in the axils of the leaves and occasionally at the base of the stem; stems erect or ascending, 1 to 10 dm. high, one to several from a common base or rootstock; leaves variable, the lowermost petiolate, rotund-ovate, oblong-ovate, obovate to narrowly oblanceolate, entire, crenate or dentate to more or less lyrate; stem-leaves petiolate to sessile, pinnatisect to entire, usually reduced towards the cymose inflorescence; heads radiate or discoid; achenes glabrous or hirtellous along the angles. Sp. 33–80.

Key to the Species

A. Stems 1 to 10 dm. high, erect or nearly so, simple or branched; heads one to many, discoid (except in *S. pauciflorus* var. *fallax*); achenes glabrous.

a. Plants small, 1.5 dm. or less high; lower leaves subentire or sharply dentate.

α. Lower leaves subentire..... *33. S. fedifolius*

β. Lower leaves sharply dentate..... *34. S. Fernaldii*

b. Plants larger, 1.5 to 10 dm. high; leaves thin in texture, the lower crenate-dentate.

[1]Issued July 7, 1916

Note.—The present paper is continued from Ann. Mo. Bot. Gard. 2:573–626. 1915.

α. Stem-leaves .5 to 3 cm. broad, usually with rather crowded divisions and narrow sinuses.

I. Heads discoid.

1. Lower leaves obovate..... 48a. *S. obovatus* var. *elongatus*

2. Lower leaves ovate..... 35. *S. pauciflorus*

II. Heads radiate ..... 35a. *S. pauciflorus* var. *fallax*

β. Stem-leaves 1 to 6 cm. broad with remote divisions and deep rounded sinuses ..... 36. *S. idahoensis*

c. Plants 1 to 6 dm. high; leaves thickish in texture, the lower entire, crenate to unequally lobate-dentate. ..... 37. *S. debilis*

B. Stems erect or ascending, .5 to 4 dm. high, simple or branched; heads radiate, usually solitary; achenes glabrous or hirtellous.

a. Leaves mostly irregularly lobed or sublyrate.

α. Achenes hirtellous ..... 38. *S. hyperborealis*

β. Achenes glabrous ..... 39. *S. resedifolius*

b. Leaves mostly or all undivided.

α. Leaves thickish in texture; heads 8 to 14 mm. high.

I. Plants glabrous or nearly so..... 40. *S. ovinus*

II. Plants white-tomentose at the base and in the leaf-axils.

1. Heads 12 to 14 mm. high; involucral bracts 21 ..... 41. *S. conterminus*

2. Heads 8 to 10 mm. high; involucral bracts 13 ..... 42. *S. hesperius*

β. Leaves thin in texture; heads 8 to 12 mm. high.

I. Plants of northern United States and Canada.

1. Lower leaves coarsely dentate. 43. *S. Newcombei*

2. Lower leaves crenate-dentate. 44. *S. subnudus*

II. Plants of Mexico..... 45. *S. Rosei*

γ. Leaves reniform to oblong-obovate, thickish in texture; heads 14 to 20 mm. high.

I. Leaves reniform ..... 46. *S. Porteri*

II. Leaves subrotund to oblong-obovate ..... 47. *S. Soldanella*

C. Stems usually erect, 1.5 to 7 dm. high, simple or branched; heads commonly several to many, usually radiate (discoid in *S. obovatus* var. *elongatus*, *S. rubricaulis* var. *aphanactis* and rarely in *S. pauperculus*).

a. Leaves thin in texture, not succulent in the living state.

α. Basal leaves obovate, subrotund to oblong-elliptic, usually glabrous.... *48. S. obovatus*

β. Basal leaves rotund-ovate, oblong-ovate to oblong-lanceolate, cordate to abruptly narrowed at the base, glabrous or glabrate.

I. Lower leaves rotund-ovate, usually deeply cordate.

1. Heads few, 1 to 3..... *49. S. Cardamine*

2. Heads several to many.

* Plants of Mexico.

† Terminal segment of stem-leaves broader than long; achenes hispidulous ..... *50. S. cyclophyllus*

†† Terminal segment of stem-leaves not broader than long; achenes glabrous ... *51. S. quebradensis*

** Plants of western United States ..... *52. S. Pammelii*

*** Plants of eastern United States ..... *53. S. aureus*

II. Lower leaves ovate to oblong-lanceolate, shallowly cordate or abruptly narrowed at the base.

1. Margins of lower leaves crenate-dentate to doubly serrate.

* Lower leaves, at least some of them, shallowly cordate.

† Basal leaves oblong-lanceolate ..... *54. S. Robbinsii*

†† Basal leaves ovate.

‖ Margins of lower leaves finely serrate with incurved teeth. *55. S. pseudaureus*

‖‖ Margins of lower leaves more coarsely and more saliently toothed.

o. Bracteoles broad, obtuse... *35a. S. pauciflorus* var. *fallax*

oo. Bracteoles narrow, acute . *56. S. Burkei*

** Lower leaves abruptly cuneate at the base, not cordate.

† Eastern species.

‖ Upper leaves pinnately divided ..... *57. S. gaspensis*

||| Upper leaves incised-serrate ..... 58. *S. Crawfordii*

†† Western species.

|Divisions of stem-leaves narrow ..... 59. *S. quaerens*

||| Divisions of stem-leaves broad ..... 60. *S. platylobus*

2. Margins of lower leaves entire or nearly so.

* Rays usually orange-red or saffron-colored ..... 61. *S. crocatus*

** Rays lemon-yellow.

† Stems closely cespitose ..... 62. *S. aquariensis*

†† Stems not closely cespitose.

|| Upper leaves conspicuously dilated into a broad amplexicaul base .... 63. *S. dimorphophyllus*

||| Upper leaves not conspicuously dilated into a broad amplexicaul base ... 64. *S. Farriae*

γ. Basal leaves oblong-ovate to lanceolate, often shallowly cordate; stems and leaves more or less persistently white-tomentulose, rarely glabrous.

I. Plants of the mountains of Arizona and New Mexico; achenes glabrous ..... 65. *S. Hartianus*

II. Plants of the low country and prairie throughout central United States; achenes usually hispidulous ..... 66. *S. plattensis*

δ. Basal leaves oblanceolate (except in *S. pauperculus* var. *firmifolius*), gradually narrowed at the base, glabrous or glabrate.

I. Plants subglaucous ..... 67. *S. Willingii*

II. Plants not at all glaucous.

1. Stems rather densely and permanently tomentose at the base; heads usually numerous. 68. *S. Smallii*

2. Stems but slightly tomentose at the base; heads comparatively few.

* Heads 5 to 9 mm. high; stems not flexuous.

† Eastern species ..... 69. *S. pauperculus*

†† Western species ..... 70. *S. flavovirens*

** Heads 10 to 13 mm. high; stems often flexuous ..... 71. *S. multnomensis*

b. Leaves usually thick or firm in texture, more or less succulent in the living state.

α. Lower leaves ovate to obovate, subentire to crenate-dentate.

I. Lower leaves broadly oval to elliptic-oblong, subentire to crenate-dentate.

1. Stems 2.5 to 5 dm. high..... *72. S. laetiflorus*

2. Stems usually lower, 1 to 2.5 dm. high ..... *73. S. Suksdorfii*

II. Lower leaves mostly obovate, entire to sharply dentate.

1. Lower leaves coarsely dentate. *74. S. rubricaulis*

2. Lower leaves entire or dentate towards the apex only..... *75. S. cymbalarioides*

β. Lower leaves mostly oblanceolate, entire or dentate chiefly towards the apex.

I. Plants 1 to 4 dm. high; cymes open, more or less flat-topped.

1. Stems tending to be leafy; leaves .5 to 2 cm. wide, achenes glabrous ..... *76. S. acutidens*

2. Stems not leafy; leaves narrower, .5–1 cm. wide; achenes hirtellous ..... *77. S. tridenticulatus*

II. Plants less than 1 dm. high; cymes close, somewhat rounded.. *78. S. Wardii*

γ. Lower leaves larger, ovate to oblanceolate, subentire to coarsely and saliently dentate with subcartilaginous teeth.

I. Leaves entire or only slightly dentate, somewhat glaucous; plants of the United States ..... *79. S. anacletus*

II. Leaves usually coarsely dentate, not glaucous; plants of Mexico. *80. S. toluccanus*

33. S. fedifolius Rydb. Bull. Torr. Bot. Club **27**:183, *pl. 5, fig. 7.* 1900, and Fl. Colo. 397. 1906; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902.

S. discoideus Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains 583. 1909, in part.

An herbaceous perennial; stem slender, 1.5 dm. high; basal leaves petiolate, blade ovate or broadly oval, 1 to 2 cm. long, entire or wavy margined; stem-leaves small, pinnately divided into short linear-oblong segments; heads 2 to 3, about 6 mm. high, discoid; involucral bracts commonly 13, lanceolate with membranous margins; achenes glabrous.

Distribution: mountains of Colorado.

Colorado: South Park, coll. of 1871, *Canby* (N. Y. College of Pharmacy Herb.), TYPE.

34. S. Fernaldii Greenm.[1]

A small herbaceous perennial, glabrous or slightly tomentose in the axils of the leaves, more or less purplish; stem erect, 1 dm. or less high, rising from an oblique rootstock; lower leaves petiolate, ovate to obovate-cuneate, including the petiole 1.5 to 3 cm. long, 1 to 1.5 cm. broad, sharply dentate; stem-leaves pinnatisect, the uppermost reduced to mere bracts; head solitary, discoid, 10 to 12 mm. high; involucre campanulate, calyculate; bracts of the involucre about 21, linear-lanceolate, 7 to 8 mm. long, a little shorter than the numerous flowers of the disk, purple; achenes glabrous.

Distribution: western Newfoundland.

Specimen examined:

Newfoundland: dry limestone barrens, upper slopes, and tablelands, Table Mountain, alt. 200–300 m., 16 Aug., 1910,

[1]**Senecio Fernaldii** Greenm. sp. nov., herbaceus perennis glabrus vel in axillis foliorum parum tomentosus plus minusve purpurascens; caule erecto 1 dm. vel minus alto; foliis inferioribus petiolatis ovatis vel obovato-cuneatis petiolo incluso 1.5–3 cm. longis 1–1.5 cm. latis acute dentatis, superioribus pinnatisectis gradatim reductis; capitulo solitario 10–12 mm. alto discoideo; involucri squamis circiter 21 lineari-lanceolatis 7–8 mm. longis; flosculis disci numerosis; achaeniis glabris. —On dry limestone barrens, upper slopes, and tablelands of Table Mountain, Newfoundland, alt. 200–300 m., 16 Aug., 1910, *Fernald & Wiegand 4188* (Gray Herb., photograph in Mo. Bot. Gard. Herb.), TYPE.

Fernald & Wiegand 4188 (Gray Herb., photograph in Mo. Bot. Gard. Herb.), TYPE.

35. S. pauciflorus Pursh, Fl. Am. Sept. **2**:529. 1814, and ed. 2, 1816; Schlecht. in Linnaea **10**:90. 1836; DC. Prodr. **6**:431. 1837; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902; Piper, Contr. U. S. Nat. Herb. **11**:597. 1906; Piper & Beattie, Fl. Northwest Coast 387. 1915.

S. aureus δ. *discoideus* Hook. Fl. Bor. Am. **1**:333. 1834; Torr. & Gray, Fl. N. Am. **2**:442. 1843, in part.

S. aureus var. *borealis* Gray, Syn. Fl. N. Am. **1**:391. 1884, and ed. 2, 1886, in part, i. e., as to *S. pauciflorus* Pursh in synonymy.

S. Lemberti Greene, Pittonia **3**:89. 1896.

S. indecorus Greene, Fl. Franciscana 470. 1897.

S. aureus pauciflorus Britt. in Britton & Brown, Ill. Fl. **3**:480. 1898.

S. discoideus Britt. in Britton & Brown, Ill. Fl. **3**:479, *fig. 4042*. 1898, and ed. 2, **3**:544, *fig. 4626*. 1913.

S. elongatus Howell, Fl. Northwest Am. **1**:379. 1900, in part, not Pursh.

S. aureus Britt. in Britton & Brown, Ill. Fl. **3**:544. 1913, in part, i. e., as to *S. pauciflorus* Pursh in synonymy.

An herbaceous perennial, glabrous or with a white-floccose tomentum in the axils of the leaves and in the inflorescence; stems one to several from a common base, erect or ascending, 1 to 10 dm. high; lower leaves petiolate, ovate-rotund to ovate-oblong, 1 to 8 cm. long, 1 to 4.5 cm. broad, crenate-dentate, glabrous on both surfaces, their petioles equalling or twice exceeding the blade; stem-leaves sublyrate to pinnatisect, the uppermost sessile and much reduced; inflorescence a few to many-headed corymbose cyme; heads discoid, 10 to 12 mm. high; involucre campanulate, calyculate; bracts of the involucre usually about 21, linear-lanceolate, acute or acutish, more or less purplish; flowers numerous; achenes glabrous.

Distribution: usually in bogs and wet places, Labrador, eastern Quebec, northern Michigan, across the continent to the

Rocky Mountains, northwest to Alaska, and south to northern California.

Specimens examined:

Labrador: specimen from the Pursh herbarium, *ex Herb. Dickson* (Phil. Acad. Nat. Sci. Herb.); without locality, *"Leconte"* (Phil. Acad. Nat. Sci. Herb.); about Hokhak and Hebron, *fratres Morav.* (Gray Herb.); northern Labrador, Lat. 58°, coll. of 1873, *Anspach* (Mo. Bot. Gard. Herb.); wet crevices of rocks, Nachvak, 1 Aug., 1884, *Bell 14778* (Geol. Surv. Canada Herb.); Long Point, Aug., 1892, *Waghorne 4* (Geol. Surv. Canada Herb. and Mo. Bot. Gard. Herb.); Capstan Island, Aug., 1893, *Waghorne 9* (U. S. Nat. Herb.); near Forteau, coll. of 1894, *Waghorne 20* (Mo. Bot. Gard. Herb.); Rama, Lat. 58°50′, July, 1894, *Sornborger* (Gray Herb.); Rama, 20–24 Aug., 1897, *Sornborger 67* (Gray Herb. and U. S. Nat. Herb.); Rama, 15 July–20 Aug., 1897, *Stecker 67ª* (Mo. Bot. Gard. Herb.); without locality, *Dr. Morrison* (Kew Herb.).

Quebec: Lake Petitsikapau, Hamilton River, 26 June, 1894, *Low 5104* (Geol. Surv. Canada Herb.); sandy shores of River Ste. Anne des Monts, Gaspé, 19 Aug., 1882, *Macoun 14808* (Geol. Surv. Canada Herb.); calcareous alpine meadow, Table-top Mountain, Gaspé Co., alt. 1000–1125 m., 7 Aug., 1906, *Fernald & Collins 261* (U. S. Nat. Herb.); on limestone conglomerate cliffs, peak west of Baptiste Michaud's, Bic, Rimouski Co., 16 July, 1904, *Collins & Fernald* (Gray Herb.); wet meadow, Bic, 22 July, 1910, *Williamson 1418* (C. S. Williamson Herb.); arbor-vitae swamps, Carleton, Bonaventure Co., 24–27 July, 1904, *Collins, Fernald & Pease* (Gray Herb.).

Ontario: wet gravelly places, Nipigon River, 2 July, 1884, *Macoun 14782* (Geol. Surv. Canada Herb.); bogs north of Port Arthur, 6 Aug., 1912, *Williamson 2148* (Phil. Acad. Nat. Sci. Herb.); Fort William, 24 July, 1912, *Williamson 1722* (Phil. Acad. Nat. Sci. Herb.); near Lake Superior, *Macoun 53* (Mo. Bot. Gard. Herb.).

Michigan: Keweenaw Peninsula, coll. of 1863, *Robbins 121* (Gray Herb.); Keweenaw Peninsula, July, 1890, and 7 July,

1915, *Farwell 776* (Gray Herb. and Mo. Bot. Gard. Herb.); Champion, July, 1889, *Hill* (Gray Herb.).

Rocky Mountains: "Grand saline, R. M. E. side," *Burke* (Gray Herb.).

Montana: Gallatin Valley, near Bozeman, alt. 1615 m., 7 July, 1896, *Flodman 908* (Mo. Bot. Gard. Herb., Greene Herb., and U. S. Nat. Herb.); wet shady places, Gallatin River, 14 July, 1905, *Blankenship 292* (Mo. Bot. Gard. Herb., Phil. Acad. Nat. Sci. Herb., Field Mus. Herb., and U. S. Nat. Herb.).

Wyoming: Little Goose Cañon, Sheridan Co., 1 July, 1901, *Nelson 2383* (Mo. Bot. Gard. Herb.); Middle Ten Sleep Creek, Big Horn Co., 1 Aug., 1901, *Goodding 465* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.).

Idaho: Forks of St. Mary's River, alt 1100 m., 3 July, 1895, *Leiberg 1158* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.).

Alberta: below Pipestone Summit, Rocky Mountain Park, 6 July, 1904, *Macoun 65018* (Gray Herb. and Geol. Surv. Canada Herb.); Blind Valley and Lakes, alt. 2130–2440 m., 6 July, 1906, *Brown 414* (Phil. Acad. Nat. Sci. Herb.); head of Snake River, 5 Aug., 1911, *Riley 32* (U. S. Nat. Herb.).

Mackenzie: Fort Franklin, Mackenzie River, *Richardson* (Geol. Surv. Canada Herb., photograph in Field Mus. Herb. and in Mo. Bot. Gard. Herb.), part of TYPE of *S. aureus* var. *discoideus* Hook.

Yukon: Ft. Selkirk, 18 July, 1899, *Tarleton 134* (U. S. Nat. Herb.); vicinity of Summit and Middle Lakes, coll. of 1898, *Bolton* (U. S. Nat. Herb.); moist glades, Red Mountain, 17 July, 1899, *Gorman 1114* (U. S. Nat. Herb.); Moosehide Mountain, Dawson, 14 July, 1902, *Macoun 78974* (Field Mus. Herb.); damp woods, West Dawson, 16 July, 1902, *Macoun 78975* (Field Mus. Herb.); Finlayson River, Lat. 61°N., *Dawson 14776* (Geol. Surv. Canada Herb.).

Alaska: south bank of Forty Mile Creek, Yukon River, 13 July, 1893, *Funston 126* (U. S. Nat. Herb.); near Knik, Oct., 1913, *Chaney* (Mo. Bot. Gard. Herb.); Kenai, 18–20 Aug., 1904, *Piper 4216* (U. S. Nat. Herb.).

British Columbia: Moose Lake, 14–24 Aug., 1911, *Riley 22* (U. S. Nat. Herb.); Kicking Horse Lake, alt. 1675 m., 15 Aug., 1890, *Macoun 14771* (Geol. Surv. Canada Herb.); Kicking Horse Valley, near Field, alt. 1230 m., 20 June–25 July, 1906, *Brown 487*[a] (Phil. Acad. Nat. Sci. Herb.); Ottertail Drive, near Field, July, 1905, *Farr 814, 820* (Univ. Penn. Herb. and Field Mus. Herb.); Wapta Lake, 4 Aug., 1904, *Macoun 65019, 65020* (Gray Herb. and Geol. Surv. Canada Herb.); Carbonate, alt. 825 m., 7 July, 1904, *Heacock 185* (Gray Herb., U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.); Upper Spillmacheen Valley, alt. 1980 m., 3 Aug., 1904, *Petersen 440* (Gray Herb., U. S. Nat. Herb., Mo. Bot. Gard. Herb., and Phil. Acad. Nat. Sci. Herb.); Cornwall Hills, 28 July, 1894, *McCoy 5100* (Gray Herb. and Geol. Surv. Canada Herb.); Skagit Valley, 28 June, 1905, *Macoun 69360* (Gray Herb.); Maclennan River, branch of Columbia River, 31 July, 1898, *Spreadborough 19727* (Geol. Surv. Canada Herb. and Greene Herb.); Chilliwack Valley, 22 June, 1901, *Macoun 26683* (Gray Herb., Geol. Surv. Canada Herb., and Mo. Bot. Gard. Herb.), *26684* and *26685* in part (Gray Herb. and Geol. Surv. Canada Herb.); alpine rivulet, Goldstream, alt. 1675 m., 25 July, 1905, *Shaw 1012* (U. S. Nat. Herb.); Alberni, Arrowsmith Trail, Vancouver Island, 27 June, 1907, *Rosendahl 1971* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Wolf Creek, Strathcona Park, Vancouver Island, 10 Aug., 1912, *Macoun 83192* (Geol. Surv. Canada Herb. and Mo. Bot. Gard. Herb.); Kasaan Mountain, Queen Charlotte Island, 7 July, 1901–02, *Newcombe 69* (Field Mus. Herb.).

Washington: Deming, Whatcom Co., 30 June, 1898, *Flett 852* in part (Piper Herb.); Big Meadows, six miles west of Ione, 6 Aug., 1902, *Kreager 428* (Gray Herb., U. S. Nat. Herb., and Piper Herb.); Mt. Constitution, Dreas Island, Aug., 1892, *Henderson 2312* (Gray Herb.).

California: Truckee, 16 June, 1901, *Williamson* (C. S. Williamson Herb.); Mt. Dana, coll. of 1866, *Bolander 6021* (Field Mus. Herb.) and *6021* in part (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Lassens Peak, July, 1896, *Austin 365* (U. S. Nat.

Herb. and Mo. Bot. Gard. Herb.); Pine Creek, Lassen Co., 9 July, 1894, *Baker & Nutting* (Greene Herb.), TYPE of *S. indecorus;* Sierra Co., coll. of 1874, *Lemmon 127* (Mo. Bot. Gard. Herb.); Sierra Nevada Mountains, coll. of 1875, *Lemmon* (U. S. Nat. Herb. 48716); Soda Springs, Tuolumne Co., July, 1894, *Lembert 171* (Gray Herb.); Yosemite Region, coll. of 1893, *Lembert* (Gray Herb. and Greene Herb. in part); Soda Springs, Mt. Conness, 6 Aug., 1890, *Harford* (Greene Herb.), TYPE of *S. Lemberti.*

To this species are also to be referred two specimens without record of locality, namely, one from the collection of Nuttall, presented by Elias Durand, 1866 (Gray Herb.), and one from the Bernhardi collection (Mo. Bot. Gard. Herb.).

Var. **fallax** Greenm. Contr. U. S. Nat. Herb. **11**:597. 1906, and in Piper & Beattie, Fl. Northwest Coast 388. 1915.

Similar in stature and in foliage to the species; heads radiate; ray-flowers 10 to 12, rays yellow; disk-flowers 50 to 60; achenes glabrous.

Distribution: occurring occasionally with the species.

Specimens examined:

Ontario: Silver Islet Beach, 4 Aug., 1914, *Williamson 2075* (C. S. Williamson Herb.); Port Arthur, 6 Aug., 1914, *Williamson 2148* (C. S. Williamson Herb.).

Michigan: Mainland Park Harbor, Isle Royal, 15–16 Aug., 1912, *Williamson 2312* (Phil. Acad. Nat. Sci. Herb.).

Alaska: along the Yukon River, near Ft. Yukon, coll. of 1881, *Bates* (U. S. Nat. Herb. 48813, 48814, and Greene Herb.).

Washington: Deming, Whatcom Co., 30 June, 1898, *Flett 852* in part (Piper Herb.).

California: Mt. Dana, coll. of 1866, *Bolander 6021* in part (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Yosemite Region, coll. of 1895, *Lembert* (Gray Herb. and U. S. Nat. Herb.); Mt. Goddard, alt. 3050 m., *Hall & Chandler 660* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); along the North Fork of Kern River, Sierra Nevada, 25 Aug., 1891, *Coville & Funston 1708* (U. S. Nat. Herb.).

36. **S. idahoensis** Rydb. Bull. Torr. Bot. Club **27**:183, *pl. 6, fig. 5.* 1900; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902.

A rather stout herbaceous perennial, 4 to 7 dm. high, glabrous or slightly white floccose-tomentulose in the axils of the leaves; stem branched from near the base, rather leafy in the lower portion, nearly naked towards the inflorescence, stramineous to somewhat purplish; leaves 2.5 to 14 cm. long, 1 to 6 cm. broad, mostly pinnately parted into oblong or somewhat cuneate subincised divisions with broad and deep rounded sinuses; inflorescence terminating the stem and branches in a several to many-headed corymbose cyme; heads discoid, 10 to 12 mm. high; involucre campanulate, calyculate; bracts of the involucre commonly 21, linear-lanceolate, 7 to 9 mm. long, acutish, more or less purplish-tipped; flowers numerous; achenes glabrous.

Distribution: Idaho, northwest into British Columbia.

Specimens examined:

Idaho: in meadows at Granite Station, Kootenai Co., 30 Aug., 1892, *Sandberg, MacDougal & Heller 803* (Gray Herb. and Phil. Acad. Nat. Sci. Herb.), CO-TYPE.

British Columbia: Griffin Lake, 6 July, 1889, *Macoun*, without number (Gray Herb.).

A species very near the preceding from which, however, it differs in the branching of the stem and by the large broad stem-leaves with cut divisions and deep rounded sinuses.

37. **S. debilis** Nutt. in Trans. Am. Phil. Soc. **7**:408. 1841; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902; Blankenship in Mont. Agr. Coll. Sci. Studies **1**:102. 1904.

S. aureus var. *discoideus* Torr. & Gray, Fl. N. Am. **2**:442. 1843, in part, i. e., as to *S. debilis* Nutt. in synonymy.

S. aureus var. *borealis* Gray, Syn. Fl. N. Am. **1**²:391. 1884, and ed. 2, 1886, in part.

S. flavovirens Rydb. Bull. Torr. Bot. Club **27**:181. 1900, in part, as to plant of Greene.

S. nephrophyllus Rydb. Mem. N. Y. Bot. Gard. 1:446. 1900, and in Bull. Torr. Bot. Club 27:183. 1900.

S. discoideus Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains 583. 1909, in part, not *S. aureus* var. *discoideus* Hook.

An erect herbaceous perennial, glabrous throughout or slightly floccose-tomentulose in the axils of the leaves and along the midrib on the upper surface of the young leaves; stems 1 to 5 dm. high; leaves thickish in texture; basal leaves petiolate, subreniform to ovate-oblong, 1 to 6 cm. long, 1 to 4 cm. broad, entire, crenately and unequally lobate-dentate; petioles variable in length from 1.5 cm. to nearly 2 dm. long; stem-leaves petiolate or sessile, sublyrate to pinnately divided into remote linear-oblong or subcuneate obtusish, often unequal, divisions and deep rounded sinuses; inflorescence terminating the stem in a few to several-headed corymbose cyme; heads 7 to 10 mm. high, discoid; flowers numerous; achenes glabrous.

Distribution: Montana and Colorado, west to Idaho and Oregon.

Specimens examined:

Montana: meadows, Big Blackfoot River, 13 July, 1883, *Canby 34* (Gray Herb.), and *203* (Phil. Acad. Nat. Sci. Herb.); Melrose, 6 July, 1895, *Shear 5011* (U. S. Nat. Herb.).

Wyoming: Laramie Plains, alt. 2590 m., 20 July, 1884, *Sheldon 73* (U. S. Nat. Herb.); Laramie, 28 July, 1889, *Greene* (U. S. Nat. Herb. and Field Mus. Herb.); Laramie hills, 17 July, 1897, *Nelson 3404* (Mont. Agr. Coll. Herb.); Laramie Plains, 21 July, 1898, *Osterhout* (Field Mus. Herb.); wet banks, City Springs, Laramie, 8 Aug., 1901, *Nelson 8599* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Laramie River, along the Medicine Bow Mountains, coll. of 1856, *H. Engelmann* (Gray Herb. and Mo. Bot. Gard. Herb.); wet meadows, Centennial, 27 July, 1900, *Nelson 7722* (Mo. Bot. Gard. Herb.); boggy draws, Centennial, 27 July, 1902, *Nelson 8685* (Gray Herb., U. S. Nat. Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.); Wind River bottom, 28 July,

1882, *Forwood* (Gray Herb. and U. S. Nat. Herb.); Meadow Creek, 9 Aug., 1894, *Nelson 906* (Gray Herb. and Greene Herb.); Bridger's Pass, coll. of 1856, *H. Engelmann* (Gray Herb.); Soldier Springs, Aug., 1891, *Nelson 177* (U. S. Nat. Herb.).

Colorado: Rocky Mountains, coll. of 1861, *Parry 19* (Phil. Acad. Nat. Sci. Herb.); Rocky Mountains, Lat. 39° 41′, coll. of 1862, *Hall & Harbour 332* in part (Mo. Bot. Gard. Herb. and Gray Herb.); Lake John, 19 Aug., 1898, *Shear & Bessey 3990* (U. S. Nat. Herb.); near High, 19 Aug., 1898, *Shear & Bessey 4005* (U. S. Nat. Herb.).

Idaho: grassy bog, One Thousand Springs Valley, alt. 2040 m., 7 Aug., 1895, *Henderson 3671* (U. S. Nat. Herb.).

Oregon: "Plains of the Oregon, near the Wahlamet," *Nuttall* (Gray Herb.), TYPE.

38. S. hyperborealis Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902; Ann. Mo. Bot. Gard. **1**:264. 1914.

S. resedifolius Hook. Fl. Bor. Am. **1**:333, *pl. 117*. 1834, in part, not Less.; DC. Prodr. **6**:347. 1837, in part; Torr. & Gray, Fl. N. Am. **2**:445. 1843, in part; Gray, Syn. Fl. N. Am. **1**²:390. 1884, and ed. 2, 1886, in part; Macoun, Cat. Canadian Pl. 267. 1884, in part, i. e., as to plant of Richardson.

Stems erect or nearly so, one to several from a perennial base, 1 to 2 dm. high, simple or branched, white-tomentose at the base and in the leaf-axils; lower leaves obovate and crenately margined to sublyrate or pinnately divided with rather remote obtusely dentate divisions, including the petiole 4 to 10 cm. long, 1 to 2.5 cm. broad; stem-leaves sessile, more or less pinnatisect, the uppermost reduced to lance-attenuate entire bracts; heads solitary or few terminating the stem and branches, 8 to 12 mm. high, radiate; involucre campanulate, sparingly calyculate, glabrous; bracts of the involucre about 13, lanceolate, acute, 5 to 6 mm. long; ray-flowers 10 to 12, rays yellow; disk-flowers rather numerous; achenes hirtellous-puberulent along the angles.

Distribution: Arctic northwest America.

Specimens examined:

Mackenzie: "on limestone at the mouth of the Bear Lake River, and about Fort Norman and Fort Franklin," *Richardson* (Gray Herb. ex Hooker, Torrey Herb., and Geol. Surv. Canada Herb. 14872 in part), CO-TYPE; west shore of Great Bear Lake, June–Aug., 1900, *Bell 22937* (Geol. Surv. Canada Herb.).

39. S. resedifolius Less. in Linnaea **6**:243. 1831; Ledeb. Fl. Rossica **2**:631. 1844–46, in major part; DC. Prodr. **6**:347. 1837, in major part; Torr. & Gray, Fl. N. Am. **2**:445. 1843, in part; Gray, Syn. Fl. N. Am. **1**²:390. 1884, and ed. 2, 1886, in part; Macoun, Cat. Canadian Pl. 267. 1884, in part; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902.

Cineraria lyrata Ledeb. in Mem. Acad. Petersb. **5**:576. 1818; Reichb. Ic. Bot. **2**:1, *pl. 101*. 1824; Hook. & Arn. Bot. Beechey's Voy. 126. 1832.

A low herb; stems one to several from a perennial base, simple or branched, .5 to 2 dm. high, glabrous or slightly tomentose, particularly in the axils of the leaves; lower leaves petiolate, rotund-ovate, sublyrate or irregularly pinnately divided, crenate to sharply dentate; upper stem-leaves sessile, more or less pinnatisect, often reduced to lance-attenuate entire bracts; heads solitary or few, radiate, about 1 cm. high, including the rays 2 to 2.5 cm. in diameter; bracts of the calyculate involucre linear-lanceolate, 6 to 8 mm. long, acuminate, acute, often purplish; achenes glabrous.

Distribution: Alaska and Siberia.

Specimens examined:

Alaska: St. Lawrence Island, *Chamisso* (Gray Herb., Berlin Herb., and Kew Herb.); Behring Strait, U. S. North Pacific Exploring Expedition, 1853–56, *Wright* (Gray Herb.); Hall Island, Behring Sea, coll. of 1885, *Thompson* (Field Mus. Herb.); Hall Island, Behring Sea, 11 Aug., 1891, *Macoun 20640* (Geol. Surv. Canada Herb.); Herschel Island, Arctic Sea, coll. of 1893, *Stringer 14390* (Geol. Surv. Canada Herb.); Port Clarence, 21 July, 1895, *Sharp* (Phil. Acad. Nat. Sci. Herb.);

Cape Nome, coll. of 1899, *Blaisdell* (Gray Herb.); vicinity of Nome, *Powers 6* (Field Mus. Herb.); Cape Vancouver, 9 Aug., 1891, *Macoun* (Geol. Surv. Canada Herb., Gray Herb., and Mo. Bot. Gard. Herb.); Kuskokwim Valley, coll. of 1884, *Weimmann* (Gray Herb.), branched form; Unga and Shumagin Islands, U. S. Coast Survey, 1871-72, *Harrington* (Gray Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.).

Var. **columbiensis** Gray, Syn. Fl. N. Am. 1²:390. 1884, and ed. 2, 1886; Macoun, Cat. Canadian Pl. 267. 1884.

S. hyperborealis var. *columbiensis* (Gray) Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. 32:20. 1902; Ann. Mo. Bot. Gard. 1:264. 1914.

Stems about 2 dm. high, one to several from a common base; heads subdiscoid, namely, with inconspicuous ray-flowers shorter than the bracts of the involucre.

Distribution: British Columbia.

Specimen examined:

British Columbia: Mucklung River, 25 July, 1882, *Mackay* (Gray Herb.), TYPE.

40. S. ovinus Greene, Pittonia 4:110. 1900; Blankenship, Mont. Agr. Coll. Sci. Studies 1:103. 1904.

S. resedifolius Rydb. Mem. N. Y. Bot. Gard. 1:447. 1900, not Less.

A low herbaceous perennial, glabrous or somewhat tawny, floccose-tomentulose in the axils of the leaves; stems one to several from an ascending stoutish rootstock, .5 to 2 dm. high, erect or nearly so; lower leaves broadly ovate to obovate, occasionally sublyrate, including the petiole 1 to 6 cm. long, the blade .5 to 3 cm. long, .3 to 2.5 cm. broad, subentire to crenate-dentate, glabrous, thickish in texture; upper leaves sessile, laciniate to entire; heads usually solitary, occasionally two, 8 to 10 mm. high, radiate; involucre campanulate, sparingly calyculate; bracts of the involucre about 21, linear-lanceolate, acuminate, acute, 7 to 8 mm. long, often purplish; ray-flowers 13 to 21, rays yellow; disk-flowers numerous; achenes glabrous.

Distribution: mountains of Alberta to Wyoming.

Specimens examined:

Alberta: high slopes of Sheep Mountain, Waterton Lake, 29 July, 1895, *Macoun 11619* (Geol. Surv. Canada Herb., Gray Herb., photograph in Field Mus. Herb. and Mo. Bot. Gard. Herb.), TYPE.

British Columbia: near the western summit of North Kootenai Pass, 26 July, 1883, *Dawson* (Geol. Surv. Canada Herb. 14826 in part, and Greene Herb.).

Montana: McDonalds Peak, Mission Range, alt. 2440 m., 19 July, 1883, *Canby 36* (Gray Herb.); Stanton Lake, 1 Aug., 1894, *Williams 1022* (Gray Herb., U. S. Nat. Herb., and Mont. Agr. Coll. Herb.); Mt. Hyalite, alt. 3000 m., 1 Aug., 1902, *Blankenship* (Gray Herb.); Sperry Glacier, 1 Sept., 1903, *Umbach 798* (Field Mus. Herb.); Sperry Glacier, alt. 2440 m., 1 Sept., 1903, *Blankenship* (Gray Herb.); MacDougal Park, Flathead Lake and vicinity, 31 July, 1908, *Clemens* (Field Mus. Herb. and Mo. Bot. Gard. Herb.); Glacier National Park, 11 July, 1914, *Hitchcock 11962* (U. S, Nat. Herb.).

Wyoming: Wind River Mountains, alt. 2700–3000 m., *"C.R."* (Gray Herb.).

41. S. conterminus Greenm. nom. nov.

S. Lyallii Klatt in Annal. Naturhist. Hofm. Wein **9**:365. 1894, not Hook. f.; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902.

A low depressed somewhat cespitose herbaceous perennial, conspicuously white-floccose tomentose at the base and in the axils of the leaves; stems erect or nearly so, 4 to 8 cm. high from a stout rootstock; leaves thickish, the lower ovate-rotund to oblong-spatulate or occasionally sublyrate, crenate-dentate to obtusely lobed, including the petiole 1 to 3 cm. long, 1 cm. or less broad; stem-leaves sessile, laciniate, the uppermost reduced to entire purplish-tipped bracts; heads usually solitary, 10 to 14 mm. high, radiate; involucre campanulate, calyculate, floccose-tomentulose at the base, glabrous above; bracts of the involucre about 21, linear-lanceolate, acuminate, 8 to 10 mm. long, somewhat penicillate, and more or less tinged with purple; ray-flowers 10 to 12, rays yellow; disk-flowers numerous, slightly exceeding the involucre; achenes glabrous.

Distribution: Rocky Mountains, near the Canadian boundary, northward into Alberta and British Columbia.

Specimens examined:

Rocky Mountain summits, alt. 2130–2440 m., Oregon Boundary Commission, coll. of 1861, *Lyall* (Gray Herb., Kew Herb., and Berlin Herb.), TYPE.

Alberta: Sheep Mountain, Waterton Lake, 28–31 July, 1895, *Macoun* (Kew Herb., Berlin Herb., and U. S. Nat. Herb. 289213); on the summit of Moose Mountain, alt. 2285 m., 29 June–1 July, 1897, *Macoun 22781, 22773* (Geol. Surv. Canada Herb.); on high mountain slopes, Crows Nest Pass, alt. 1825–2285 m., 2 Aug., 1897, *Macoun 22782, 22783* in part (Geol. Surv. Canada Herb.).

British Columbia: north summit of North Kootenai Pass, coll. of 26 July, 1883, *Dawson* (Geol. Surv. Canada Herb. 14826 in part).

42. S. hesperius Greene, Pittonia **2**:166. 1891. Pl. 3, fig. 1.

S. hesperis Howell, Fl. Northwest Am. **1**:375. 1900.

S. pyroloides Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902.

S. auleticus Greene, Leafl. Bot. Obs. & Crit. **2**:15. 1909.

A slender herbaceous perennial; stem erect, 1 to 2 dm. high, floccose-tomentulose, especially at the base and in the axils of the leaves, later more or less glabrate, obovate-rotund to oblanceolate, including the petiole 1 to 6 cm. long, .5 to 1.8 cm. broad, entire to crenate-dentate, narrowed at the base into a petiole equalling or much exceeding the blade, at first tomentulose soon glabrate; stem-leaves sessile, laciniate to linear-attenuate; heads usually solitary, occasionally two, rarely five, 10 to 12 mm. high, radiate; involucre campanulate, sparingly calyculate, slightly tomentulose to glabrous; bracts of the involucre 13 to 21, linear-lanceolate, 5 to 8 mm. long; rays yellow; disk flowers rather numerous; achenes glabrous.

Distribution: southwestern Oregon.

Specimens examined:

Oregon: Eight Dollar Mountain, May, 1884, *Howell 160* (Gray Herb.); near Kirbyville, 27 May, 1884, *Howell 1511*

(Greene Herb., U. S. Nat. Herb., Torrey Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb), TYPE; Eight Dollar Mountain, 13 June, 1904, *Piper 6145* (U. S. Nat. Herb.); eight miles south of Waldo, 14 June, 1904, *Piper 6254* (U. S. Nat. Herb.).

43. S. Newcombei Greene, Pittonia **3**:249. 1897.

A slender herbaceous perennial, glabrous throughout; stem solitary, erect or nearly so, 1.5 to 2 dm high; leaves thin, the lower petiolate, reniform to obovate in general outline, 3 to 7-lobate-dentate, 1 to 1.5 cm. long, 1 to 2 cm. broad, subcordate to abruptly narrowed at the base into a slender petiole, the lobes ovate-oblong, mucronate; upper leaves cuneate to linear; heads solitary, radiate, about 1 cm. high; involucre subcampanulate, ecalyculate, glabrous; bracts of the involucre 8 to 13, lanceolate, 6 to 8 mm. long, acute; ray-flowers 10 to 12, rays narrowly oblong, 1 to 1.5 cm. long, 2 to 4 mm. broad, in the dried state more or less tinged with lilac; disk-flowers rather numerous; achenes striate, glabrous.

Distribution: known only from Queen Charlotte Islands.

Specimens examined:

British Columbia: Kaitgoro, west coast of Moresby Island, Queen Charlotte Islands, 28 June, 1897, *Newcombe* (Greene Herb., Geol. Surv. Canada Herb. 18707, and Kew Herb., tracing in Gray Herb.), TYPE; in the same locality, coll. of 1903, *Newcombe* (Field Mus. Herb. and Gray Herb.).

This species is known only from its original station, and while it exhibits certain characteristics not common in *Senecio*, yet it has the technical floral characters of this genus.

44. S. subnudus DC. Prodr. **6**:428. 1837; Nutt. in Trans. Am. Phil. Soc. **7**:412. 1841; Torr. & Gray, Fl. N. Am. **2**:445. 1843; Howell, Fl. Northwest Am. 378. 1900; Rydb. Mem. N. Y. Bot. Gard. **1**:447. 1900, and Bull. Torr. Bot. Club **27**:184. 1900; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902; Piper, Contr. U. S. Nat. Herb. **11**:597. 1906; Coulter & Nelson, Manual Cent. Rocky Mountains 582. 1909.

S. aureus var. *subnudus* Gray, Syn. Fl. N. Am. 1^2:391. 1884, and ed. 2, 1886; Macoun, Cat. Canadian Pl. 266. 1884.

S. cymbalarioides Buek, Ind. DC. Prodr. pt. 2, p. vi. 1840, not Nutt.

A slender herbaceous perennial, glabrous throughout; stem simple, erect, 1 to 3.5 dm. high, rising from a slender rootstock; leaves thin, membranous, the lower petiolate, subrotund-obovate, occasionally sublyrate, including the petiole .5 to 9 cm. long, .5 to 3 cm. broad, abruptly to gradually narrowed at the base, crenate-dentate; the upper leaves sessile, incised to entire; heads solitary or occasionally two, 8 to 10 mm. high, including the yellow rays 1.5 to 2.5 cm. in diameter; bracts of the involucre about 21, linear-lanceolate, acute, glabrous and often purplish, slightly shorter than the rather numerous flowers of the disk; achenes glabrous.

Distribution: Montana and Wyoming to Washington and California.

Specimens examined:

Montana: bogs, Park Co., alt. 2800 m., Aug., 1897, *Tweedy 344* (Mont. Agr. Coll. Herb.); in open bogs among the hills, West De Lacy Creek, 4 Aug., 1899, *A. & E. Nelson 6300* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Old Hollowtop, near Pony, alt. 2740 m., 7 July, 1897, *Rydberg & Bessey 5270* (Gray Herb., U. S. Nat. Herb., Field Mus. Herb., and Mont. Agr. Coll. Herb.).

Yellowstone National Park: Upper Falls of the Yellowstone, Hayden's U. S. Geol. Survey, 1871, *Adams* (U. S. Nat. Herb.); in bogs, alt. 2740 m., Aug., 1885, *Tweedy 720* (U. S. Nat. Herb. 143107, and Field Mus. Herb.).

Rocky Mountains: Lat. 49° N., alt. 1980 m., Oregon Boundary Commission, 1861, *Lyall* (Gray Herb.).

Wyoming: without definite locality or date of collection, *Tweedy 585* (U. S. Nat. Herb. 48711); Wind River Chain of Rocky Mountains, alt. 2135 m., *Fremont* (Gray Herb.).

Idaho: ridges south from Wiessner's Peak, alt. 1900 m., 27 July, 1895, *Leiberg 1376* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Bear Creek Cañon, alt. 1500 m., 1 Sept., 1897, *Leiberg 2968* (U. S. Nat. Herb.).

Washington: Horse Shoe Basin, Okanogan Co., Sept., 1897, *Elmer 1423* (Mo. Bot. Gard. Herb.); Yakima region,

Northern Transcontinental Survey, coll. of 1882, *Brandegee 118* (Mo. Bot. Gard. Herb.) and *915* (Gray Herb.); wet meadows, Chiquash Mountains, Skamania Co., 18 Aug., 1892, *Suksdorf 2167* (Gray Herb., U. S. Nat. Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.); north of Mt. Adams, Aug., 1892, *Henderson 2308* (Gray Herb.); wet meadows, alt. about 2000 m., Mt. Paddo (Adams), 3 Sept., 1904, *Suksdorf 4241* (U. S. Nat. Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.).

Oregon: Eagle Creek Mountains, Union Co., alt. 2440 m., Aug., 1881, *Cusick 938, 959* (Gray Herb.); wet meadows of the highest mountains, eastern Oregon, coll. of 1897, *Cusick 1804* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); granitic soil, swampy meadows, North Catherin Creek, eastern Oregon, alt. 1500 m., 26 July, 1907, *Cusick 3177* (U. S. Nat. Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.); sedgy meadow, Wallowa Mountains, source of Kettle Creek, alt. 2285 m., 12 Aug., 1909, *Cusick 3379* (U. S. Nat. Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.); "Cascade Mountains on the Oregon" *(Douglas?) Dr. Gairdner* (Gray Herb.); without locality, coll. of 1871, *Hall 304* (Gray Herb. and Mo. Bot. Gard. Herb.); base of Mt. Hood, June, 1878, *J. & S. J. Howell* (Field Mus. Herb.); Mt. Hood, alt. 1220 m., 25–26 Aug., 1914, *Hitchcock 12328* (U. S. Nat. Herb.); Cascade Mountains, Aug., 1880, *Howell* (U. S. Nat. Herb. 48811, and Field Mus. Herb.).

California: Plumas Co., coll. of 1876, *Mrs. Austin* (Gray Herb. and Field Mus. Herb.); summit of Mt. Dana, coll. of 1878, *Lemmon* (Gray Herb.); Pine Creek, July, 1912, *Baker* (Field Mus. Herb.).

45. **S. Rosei** Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902; Field Col. Mus. Bot. Ser. **2**:276. 1907. Pl. 3, fig. 2.

An herbaceous perennial; stem solitary, erect, 4 to 4.5 dm. high, simple, glabrous below, slightly pubescent above, terminated by a single large radiate head; lower leaves petiolate, ovate, 2 to 3 cm. long, two-thirds as broad, obtuse, subentire to crenate-dentate, thin, glabrous on both surfaces; petioles

2.5 to 8 cm. long; upper stem-leaves sublaciniate and somewhat ampliated at the base and partly clasping the stem; heads about 12 mm. high, including the rays 3 to 3.5 cm. in diameter; involucre campanulate, essentially ecalyculate; bracts of the involucre lanceolate-linear, 8 to 10 mm. long, acute, glabrous; ray-flowers 10 to 12, rays light yellow, conspicuous; disk-flowers numerous; achenes glabrous.

Distribution: west central Mexico.

Specimen examined:

Territory of Tepic: Sierra Madre, near Santa Teresa, 10 Aug., 1897, *Rose 2157* (Gray Herb. and U. S. Nat. Herb.), TYPE.

46. **S. Porteri** Greene, Pittonia 3:186. 1897; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. 32:20. 1902; Rydb. Fl. Colo. 397. 1906.

S. renifolius Porter in Porter & Coulter, Syn. Fl. Colo. 83. 1874, not Schz. Bip.; Gray, Syn. Fl. N. Am. 1²:389. 1884, and ed. 2, 1886; Coulter, Manual Rocky Mountain Region 210. 1885.

A low herbaceous perennial, glabrous throughout and more or less tinged with purple; stems ascending from a slender rootstock, 1 dm. or less high; leaves petiolate, mostly reniform, including the petiole 1.5 to 5 cm. long, .8 to 2.5 cm. broad, crenate; heads about 14 mm. high, solitary on nearly naked peduncles, radiate; involucre campanulate, sparingly calyculate; bracts of the involucre about 13, linear-lanceolate, acute, 10 mm. long, purplish; ray-flowers 8 to 10, rays bright yellow; disk-flowers numerous; achenes glabrous.

Distribution: high mountains of Colorado and eastern Oregon.

Specimens examined:

Colorado: White House Mountain, alt. 3960 m., Hayden's U. S. Geol. Survey, 9 Aug., 1873, *Coulter 2950* (Gray Herb., Phil. Acad. Nat. Sci. Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.).

Oregon: alpine ridges of the Wallowa Mountains, 3 Aug., 1899, *Cusick 2305* (Gray Herb., Kew Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.).

47. **S. Soldanella** Gray, Proc. Acad. Nat. Sci. Phil. **15**:67. 1863; Porter & Coulter, Syn. Fl. Colo. 83. 1874; Gray, Syn. Fl. N. Am. 1^2:384. 1884, and ed. 2, 1886; Coulter, Manual Rocky Mountain Region 206. 1885; Rydb. Fl. Colo. 394. 1906; Coulter & Nelson, Manual Cent. Rocky Mountains 578. 1909; Clements & Clements, Rocky Mountain Fls. 291. 1914.

S. Grayi Parry ex Gray, Proc. Acad. Nat. Sci. Phil. **15**:67. 1863, not *S. Greyi* Hook. f.

A low herbaceous perennial, 1 to 2 dm. high, glabrous throughout and more or less tinged with purple; stems flexuous, ascending from a stoutish rootstock, the latter bearing numerous fleshy-fibrous roots; leaves somewhat succulent, subrotund to oblong-obovate, 1.5 to 5.5 cm. broad, entire to sinuate-dentate, subcordate or more frequently cuneate at the base into a winged petiole much exceeding the blade; heads large, 1.5 to 2 cm. high, usually solitary, radiate; involucre broadly campanulate, calyculate; bracts of the involucre narrowly lanceolate, 10 to 14 mm. long, pubescent-tipped, otherwise glabrous and purplish; ray-flowers 10 to 18, rays yellow; disk-flowers very numerous; achenes strongly ribbed, glabrous.

Distribution: high mountains of Colorado.

Specimens examined:

Colorado: Gray's Peak, 1 Aug., 1862, *Parry* (Gray Herb., Kew Herb., and Mo. Bot. Gard. Herb.), TYPE; Lat. 39°41′ N., coll. of 1862, *Hall & Harbour 319* (Gray Herb., Kew Herb., U. S. Nat. Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.); South Park, alt. 3960 m., Lieut. Wheeler's Expedition, 1873, *Wolf & Rothrock 573, 575* (Gray Herb. and U. S. Nat. Herb.); Mt. La Plata, alt. 4265 m., Hayden's U. S. Geol. Survey, 1873, *Coulter* (Gray Herb. and Field Mus. Herb.); Sangre de Cristo, Aug., 1873, *Brandegee 724* (U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.); Sawatche Range, coll. of 1880, *Brandegee* (Mo. Bot. Gard. Herb.); high mountains, Gray's Peak and vicinity, alt. 3350–4265 m., Aug., 1885, *Patterson 84* (Gray Herb., Kew Herb., U. S. Nat. Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.); Gray's Peak, alt.

4265 m., 21 July, 1886, *Letterman 67* (Mo. Bot. Gard. Herb.); Gray's Peak, July, 1888, *Eastwood* (U. S. Nat. Herb.); Mt. Baldy, alt. 3655 m., 11 July, 1891, *Smith* (Mo. Bot. Gard. Herb.); Mt. Princeton, alt. 2115 m., 21 July, 1892, *Sheldon 172, 491* (U. S. Nat. Herb.); stony slopes of Sheep Mountain, alt. 4225 m., coll. of July, 1893, *Purpus 680* (Field Mus. Herb.); La Plata Mountains, alt. 3350–3600 m., 15 July, 1896, *Tweedy 536* (U. S. Nat. Herb.); Cameron Pass, alt. 3600 m., 16 July, 1896, *Baker* (Mo. Bot. Gard. Herb.); Cumberland Mine, La Plata Mountains, alt. 3750 m., 15 July, 1898, *Baker, Earle & Tracy 534* (Gray Herb., Kew Herb., U. S. Nat. Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.); Mt. Baldy, near Breckenridge, alt. 3960 m., Aug., 1901, *Mackenzie 164* (Phil. Acad. Nat. Sci. Herb. and Mo. Bot. Gard. Herb.).

48. S. obovatus Muhl. ex Willd. Sp. Pl. **3**:1999. 1804; Pursh, Fl. Am. Sept. **2**:530. 1814, and ed. 2, 1816; Nutt. Gen. **2**:165. 1818; Ell. Sketch 329. 1824; Eaton, Manual of Botany 454. 1824; DC. Prodr. **6**:432. 1837; Heller, Cat. N. Am. Pl. 146. 1898, and ed. 2, 230. 1900; Britton & Brown, Ill. Fl. **3**:478, *fig. 4041*. 1898, and ed. 2, 545, *fig. 4627*. 1913; Britton, Manual 1027. 1901, and ed. 2, 1905; Greenm. Rhodora **3**:5. 1901; Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902; Porter, Fl. Penn. 339. 1903; Keller & Brown, Handb. Fl. Phil. and Vicinity 343. 1905; Small, Fl. Southeastern United States 1304. 1903, and ed. 2, 1913; Greenm. in Gray, Manual, ed. 7, 854. 1908; Graves et al. Conn. Geol. and Nat. Hist. Surv. Bull. No. 14, p. 404. 1910; Small & Carter, Fl. Lancaster County 310. 1913.

S. obtusatus Banks ex Pursh, Fl. Am. Sept. **2**:530. 1814, and ed. 2, 1816; DC. Prodr. **6**:432. 1837.

S. Elliottii Torr. & Gray, Fl. N. Am. **2**:443. 1843; Chapman, Fl. Southern U. S., ed. 1, 245. 1860, and ed. 2, 1889.

S. aureus var. *obovatus* Torr. & Gray, Fl. N. Am. **2**:442. 1843; Gray, Syn. Fl. N. Am. 1^2:391. 1884, and ed. 2, 1886; Macoun, Cat. Canadian Pl. 265. 1884, in part; Chapman, Fl. Southern U. S., ed. 3, 266. 1897.

An herbaceous perennial, glabrous or slightly tomentulose; stems erect, 2 to 5 dm. high, simple or branched, often stoloni-

ferous at the base; stolons slender and elongated to short and rather stout; lower leaves petiolate, obovate, oblong-ovate to subrotund, 1 to 10 cm. long, two-thirds to nearly or quite as broad, rounded at the apex, crenate to doubly serrate, gradually narrowed at the base and decurrent on the petiole or abruptly contracted to a subcordate base; stem-leaves petiolate and sublyrate to sessile, more or less pinnatisect and semiamplexicaul; inflorescence a terminal several to many-headed corymbose cyme; heads 8 to 10 mm. high, radiate; ray-flowers 8 to 12, rays relatively long and narrow, yellow; disk-flowers numerous; achenes glabrous or occasionally hispidulous along the angles.

Distribution: Vermont, south to Georgia, west to Missouri, Kansas, and Texas.

Specimens examined:

Vermont: Pownal, Bennington Co., 31 July, 1898, *Eggleston 264* (Gray Herb.), and 8–11 Sept., 1899, *Eggleston 1381* (U. S. Nat. Herb.).

Massachusetts: Ipswich, coll. of 1842, *Oakes* (Gray Herb. and U. S. Nat. Herb.); Boxford, 22 June, 1878, *E. Faxon* (Gray Herb.); Alford, *Milligan* (U. S. Nat. Herb.); without definite locality, *Nuttall* (Phil. Acad. Nat. Sci. Herb.).

Connecticut: shaded limestone ledges, Salisbury, 3 June, 1901, *Bissell* (Gray Herb.); in loam and on calcareous ledges, Salisbury, 30 May, 1902, *Churchill, Bissell & Fernald 96* (Gray Herb., U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.); near Southington, 24 Aug., 1903, *Andrews* (Gray Herb.); Meriden Mountain, 30 May, 1885, *Safford 344* (U. S. Nat. Herb.); rich dry rocky woods, Monroe Co, 8 June, 1895, *Eames* (U. S. Nat. Herb.); thin dry woods on ledge of trap rock, Long Hill, 26 May, 1894, *Eames* (Gray Herb.); Bridgeport, 19 May, 1893, *Eames* (U. S. Nat. Herb.).

New York: Lebanon Springs, 31 May, 1890, *Harrison 9* (U. S. Nat. Herb.); West Point, *ex Herb. Thurber* (Gray Herb.); Van Cortlandt, May, 1893, *Pollard* (U. S. Nat. Herb.); Delaware Co., 6 July, 1892, *H. von Schrenk* (Mo. Bot. Gard. Herb.); without definite locality, *Torr. & Gray, Fl. N. Am.* (Gray Herb.).

New Jersey: dry soil, Cranberry Lake, Sussex Co., 9 June, 1907, *Mackenzie 2616* (U. S. Nat. Herb.); Budd's Lake, Morris Co., 29 May, 1895, *Heritage*, in part, and 30 May, 1895, *Leppanett*, in part (Phil. Acad. Nat. Sci. Herb.); rocky banks, near Charlotteburg, Morris Co., 24 May, 1908, *Mackenzie 3089* (Mo. Bot. Gard. Herb.); above Phillipsburg, Warren Co., 18 May, 1907, *Van Pelt & Long* (Phil. Acad. Nat. Sci. Herb.).

Pennsylvania: Stroudsburg, 2 June, 1900, *ex Herb. Canby* (Phil. Acad. Nat. Sci. Herb.); Bartonsville, 1 July, 1907, *Long & Bartram* (Phil. Acad. Nat. Sci. Herb.); side of Pocono Knob, 31 May, 1902, *Brown* (Phil. Acad Nat. Sci. Herb.); Easton, *Teall Green* (Gray Herb.); Buckskill Falls, 31 May, 1897, *Brown* (Phil. Acad. Nat. Sci. Herb.); Hellertown, 1 June, 1849, *ex Herb. Detwiller* (Phil. Acad. Nat. Sci. Herb.); along Jordan Creek, Lehigh Co., 14 May, 1911, *Preston 3366* (Phil. Acad. Nat. Sci. Herb.); Nockamixon, 28 May, 1893, *MacElwee*, in part, 19 May, 1906, *Van Pelt & Long*, 26 May, 1902, *Fretz*, and 4 June, 1894, *Crawford* (Phil. Acad. Nat. Sci. Herb.); Nockamixon Rocks, 30 May, 1893, *N. L. Britton* (U. S. Nat. Herb.); Narrowsville, 30 May, 1893, *Brown* (Phil. Acad. Nat. Sci. Herb.); Ivy Rock, below Norristown, 9 May, 1896, *Keller*, and 6 May, 1906, *Van Pelt* (Phil. Acad. Nat. Sci. Herb.); Pennsburg, 20 June, 1910, *Mumbower 255* (Phil. Acad. Nat. Sci. Herb.); Areola, *ex Herb. Crawford* (Phil. Acad. Nat. Sci. Herb.); Phoenixville, June, 1865, *ex Herb. Martindale*, and 25 April, 1909, *Bartram* (Phil. Acad. Nat. Sci. Herb.); near Philadelphia, *Griffith 30* (Phil. Acad. Nat. Sci. Herb.); Philadelphia, *ex Herb. Bernhardi* (Mo. Bot. Gard. Herb.); Schuylkill, 5 May, 1834, collector not indicated (Phil. Acad. Nat. Sci. Herb.); Lafayette and Sumneytown, *Williamson* (C. S. Williamson Herb.); in limestone on the Conestoga near Danville Pike Crossing, 17 May, 1901, *Heller* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Conestoga, April, 1889, *Ehy* (Mo. Bot. Gard. Herb.); Mountville, Lancaster Co., April, 1889 and 1890, *Ehy* (Mo. Bot. Gard. Herb.); McConnellsburg, Fulton Co., 3 June, 1905, *Stone 334* (Phil. Acad. Nat. Sci. Herb.); Johnstown, Cambria Co., *Williams* (C. S.

Williamson Herb.), and 16 June, 1907, *Bartram* (Phil. Acad. Nat. Sci. Herb.); Homewood, 15 June, 1907, *Bartram* (Phil. Acad. Nat. Sci. Herb.); Ohiopyle, Fayette Co., 3–8 July, 1905, *Brown, Crawford & Van Pelt 22, 135* (Phil. Acad. Nat. Sci. Herb.).

Virginia: Great Falls of the Potomac, 21 April, 1908, *Williamson* (Phil. Acad. Nat. Sci. Herb.); on limestone cliffs at edge of river near Schulers, west of Luray, Page Co., 10 May, 1904, *G. S. Miller* (U. S. Nat. Herb.); about Mt. Crawford, Rockingham Co., alt. 365–455 m., 5–13 May, 1893, *Heller* (U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.); bluffs of Middle Fork of Holston River, near Marion, Smyth Co., alt. 640 m., 22 May, 1892, *Small* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); vicinity of Marion, 22 May, 1892, *N. L. and E. G. Britton & Vail* (Phil. Acad. Nat. Sci. Herb.).

North Carolina: rocky woods, Hewitt's Station, Swain Co., 24 May, 1897, *Biltmore Herb. 3364a* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Hot Springs and Warm Springs, 24 April, 1887, *Aubrey H. Smith* (Phil. Acad. Nat. Sci. Herb.).

South Carolina: slopes of Paris Mountain, Greenville, 2 April, 1908, *Mackenzie* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.), tomentulose form.

Georgia: bluffs, Rome, coll. of 1882, *ex Herb. Chapman* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.), a form approaching the variety *rotundus*.

Alabama: Boykin, *Buckley* (Gray Herb.); Moulton, Lawrence Co., *Mohr* (U. S. Nat. Herb.); without definite locality, *Wilkinson* (U. S. Nat. Herb.).

West Virginia: White Sulphur Springs, 17–18 May, 1909, *Eggleston 4346* (Mo. Bot. Gard. Herb.); Fairmont, May, 1907, *Williamson* (C. S. Williamson Herb.).

Ohio: near Canton, May, 1875, *ex Herb. Riddell 149* (Mo. Bot. Gard. Herb.); river banks, Lorain Co., 21 April, 1890, *Kofoid* (Mo. Bot. Gard. Herb.); Huron River, Erie Co., *Moseley* (Gray Herb.); Oxford, 2 June, 1908, *Overholts* (Mo. Bot. Gard. Herb.).

Indiana: around lakes, Wells Co., 11 May, 1903, *Deam* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); river bank, north of Notre Dame, 6 June, 1911, *Nieuwland 2660*, and 15 May, 1913, *Nieuwland 11114* (Mo. Bot. Gard. Herb.); Worthington, 29 April, 1889, *Evermann* (U. S. Nat. Herb.).

Kentucky: beargrass hills near Louisville, 20 May, 1853, *Mohr* (U. S. Nat. Herb.); without definite locality, *cf Herb. Short* (Phil. Acad. Nat. Sci. Herb.).

Tennessee: rich bluffs, Knoxville, May, 1896, *Ruth (2)* and in woods, near Knoxville, June, 1896, *Ruth 5* (Mo. Bot. Gard. Herb.); Knoxville, 5 May, 1895, *J. G. Smith* (Mo. Bot. Gard. Herb.); moist woods, Cumberland Mountain, 5 May, 1898, *Eggert* (Mo. Bot. Gard. Herb.); cedar glades, near Lavergne, 4 May, 1898, *Eggert* (Mo. Bot. Gard. Herb.).

Missouri: Jerome, colls. of 1913 and 1914, *J. H. Kellogg 56, 58, 90, 452* (Mo. Bot. Gard. Herb.); Swan, 21 April, 1907, *Bush 4203* (Mo. Bot. Gard. Herb.); Monteer, 12 May, 1901, *Bush 429*, and 14 May, 1905, *Bush 2836* (Mo. Bot. Gard. Herb.); on bluffs, Neck City, Jasper Co., 12 May, 1912, *E. J. Palmer 3669* (Mo. Bot. Gard. Herb.).

Arkansas: Independence, 23 April, 1896, *Eggert* (Mo. Bot. Gard. Herb.); Eureka Springs, 20 April, 1899, *Trelease* (Mo. Bot. Gard. Herb.); Hartford Station, April, 1903, *Pilsbury* (Phil. Acad. Nat. Sci. Herb.); Petit Jean, Yell Co., 1 and 2 April, 1903, *Pilsbury* (Phil. Acad. Nat. Sci. Herb.).

Oklahoma: Vinita, 23 April, 1891, *Carleton 19* (U. S. Nat. Herb.); on creek bank, Page, Leflore Co., 20 April, 1915, *Blakeley 3443* (Mo. Bot. Gard. Herb.).

Texas: river banks, Denison, 28 March, 1890, *Bodin 27* (U. S. Nat. Herb.); near Austin, 17 March, 1908, *York* (Mo. Bot. Gard. Herb.).

Var. **divisifolius** Greenm. var. nov.

Stems bearing short stout stolons; lower leaves obovate to narrowly oblong-oblanceolate, those of the stem relatively long and conspicuously pinnatisect. A local but striking variation from the type.

Distribution: bluffs near Knoxville, Tenn.

Specimens examined:

Tennessee: rich woods, Knoxville, April, 1898, *Ruth 705* (Mo. Bot. Gard. Herb.), TYPE; bluffs, Knoxville, April, 1898, *Ruth 674* (U. S. Nat. Herb.); bluffs, Knoxville, May, 1896, *Ruth (3)* (Mo. Bot. Gard. Herb.); vicinity of Knoxville, 29 April, 1890, *Lamson-Scribner* (U. S. Nat. Herb.).

Var. **elongatus** (Pursh) Britt. in Britton & Brown, Ill. Fl. **3**:478. 1898; Britton, Manual 1027. 1901, and ed. 2, 1905; Porter, Fl. Penn. 339. 1903; Keller & Brown, Handb. Fl. Phil. and Vicinity 343. 1905; Greenm. Monogr. Senecio, I. Teil, 24. 1901, in Engl. Bot. Jahrb. **32**:20. 1902, and in Gray, Manual, ed. 7, 854. 1908.

S. elongatus Pursh, Fl. Am. Sept. **2**:529. 1814, and ed. 2, 1816.

S. aureus var. *discoidea* Porter in herb., not *S. aureus* var. *discoideus* Hook.

Habit and foliage of the species; peduncles of the inflorescence relatively long; heads discoid.

Distribution: eastern Pennsylvania and New Jersey.

Specimens examined:

New Jersey: Budd's Lake, Morris Co., 29 May, 1895, *Heritage,* in part, and 30 May, 1895, *Lippincott,* in part (Phil. Acad. Nat. Sci. Herb.).

Pennsylvania: vicinity of Easton, coll. of 1807, *Pursh, ex Herb. Lambert* (Gray Herb.); College Hill, Easton, June, 1867, *Porter* (Gray Herb.); College Hill, 1 June, 1868, *Porter,* and coll. of 1868, *Garber* (Phil. Acad. Nat. Sci. Herb.); College Hill, June, 1870, *Porter* (U. S. Nat. Herb.); College Hill, May, 1871, *Porter* (Mo. Bot. Gard. Herb.); Spruce Hill on Bushkill Creek, 25 May, 1887, *Porter* (Phil. Acad. Nat. Sci. Herb.); College Hill, 12 May, 1890, *Porter* (Gray Herb. and U. S. Nat. Herb.); Nockamixon, Bucks Co., 28 May, 1893, MacElwee (Phil. Acad. Nat. Sci. Herb.), in part; College Hill, 17 May, 1895, *Porter* (Phil. Acad. Nat. Sci. Herb.); limestone bluffs on the Bushkill, 5 May, 1899, *Porter* (Phil. Acad. Nat. Sci. Herb.); "hillsides, near the Schuylkill and Susquehanna", *ex. Herb. David Townsend* (Phil. Acad. Nat. Sci. Herb.).

Var. **rotundus** Britt. in Britton & Brown, Ill. Fl. 3:479. 1898. Britton, Manual 1027. 1901, and ed. 2, 1905; Greenm. Monogr. Senecio, I. Teil, 24. 1901, in Engl. Bot. Jahrb. **32**:20. 1902, and in Gray, Manual 854. 1908; Blankenship in Mo. Bot. Gard. Ann. Rept. **18**:179. 1907.

S. rotundus Small, Fl. Southeastern U. S. 1304. 1903, and ed. 2, 1913.

S. Lindheimeri Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902.

Habit, inflorescence, and technical characters of the head like the species; basal leaves usually long-petioled, the blade obovate to subrotund, cuneate to abruptly constricted into a subcordate base.

Distribution: Ohio to eastern Kansas and south to Louisiana and Texas.

Specimens examined:

Ohio: Oak Point, Lorain Co., 11 May, 1895, *Ricksecker* (U. S. Nat. Herb.); Franklin Co., 7 May, 1892, *Werner 133* (Gray Herb.); central Ohio, *Sullivant* (Gray Herb.); vicinity of Miami, coll. of 1835, *Dr. Frank* (Mo. Bot. Gard. Herb.); Dayton, collector not indicated (Gray Herb.); near Cincinnati, *Lloyd* (Mo. Bot. Gard. Herb.).

Missouri: flood plain of Fox Creek, near Allenton, St. Louis Co., 25 May, 1914, *Drushel* (Mo. Bot. Gard. Herb. and J. A. Drushel Herb.); wet places near Glencoe, 22 May, 1879, *Eggert* (Mo. Bot. Gard. Herb.); Meramec Highlands, 7 May, 1898, *Norton* (Mo. Bot. Gard. Herb.); Pacific, 24 May, 1915, *Drushel* (J. A. Drushel Herb.); Jefferson City, 6 May, 1866, *Krause* (Mo. Bot. Gard. Herb.); Kimmswick, 10 May, 1885, *Wislizenus 226* (Mo. Bot. Gard. Herb.), in part; Monteer, 11 May, 1905, *Bush 2822* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Pleasant Grove, 20 May, 1900, *Bush 340, 710* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); near Webb City, 4 May, 1902, *E. J. Palmer 314* (Mo. Bot. Gard. Herb.); Oronogo, 13 and 30 May, 1906, *E. J. Palmer 859* (Mo. Bot. Gard. Herb.); La Russell, 22 May, 1908, *E. J. Palmer 1342* (Mo. Bot. Gard. Herb.); Prosperity, 11 May, 1909, *E. J. Pal-*

mer 1667 (Mo. Bot. Gard. Herb.); Alba, 30 May, 1909, *E. J. Palmer 1834* (Mo. Bot. Gard. Herb.); Carterville, 14 April, 1912, *E. J. Palmer 3521* (Mo. Bot. Gard. Herb.); Eagle Rock, 22 May, 1898, *Bush 262* (Mo. Bot. Gard. Herb.); open ground, McDonald Co., 24 May, 1891, *Bush 871* (Mo. Bot. Gard. Herb.); rich hillside woods, Noel, 4 May, 1914, *E. J. Palmer 5478* (Mo. Bot. Gard. Herb.).

Arkansas: Fulton, 18 April, 1901, *Sargent, Trelease & Bush 143* (Phil. Acad. Nat. Sci. Herb.); Texarkana, 6 April, 1905, *Bush 2241* (Mo. Bot. Gard. Herb.).

Louisiana: without definite locality, *Hale* (Gray Herb.).

Kansas: wet soil, Bourbon Co., 5 May, 1897, *Hitchcock 1118* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.).

Oklahoma: Sapulpa, 29 April, 1895, *Bush 976* (Mo. Bot. Gard. Herb.).

Texas: San Augustine, *Crocket* (U. S. Nat. Herb. 500119); Livingston, Polk Co., 9 April, 1914, *E. J. Palmer 5189* (Mo. Bot. Gard. Herb.); Grand Saline, *Reverchon* (Mo. Bot. Gard. Herb.); Marshall, Harrison Co., 17 April, 1914, *E. J. Palmer 5285* (Mo. Bot. Gard. Herb.); Mill Creek bottom, Washington Co., 26 Feb., 1844, *Lindheimer* (Mo. Bot. Gard. Herb. and Gray Herb.); rich woods, Dallas, 13 March, 1901, *Reverchon 556* (Mo. Bot. Gard. Herb.); Gillespie Co., *Jermy* (Mo. Bot. Gard. Herb.); Comal Spring, New Braunfels, *Lindheimer 446* (Mo. Bot. Gard. Herb.); New Braunfels, colls. of 1850 and 1851, *Lindheimer 510, 958, 959, 960* (U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.); New Braunfels, alt. 228 m., 17–19 April, 1903, *Pilsbury* (Phil. Acad. Nat. Sci. Herb.); without definite locality, *Wright* (Gray Herb.).

Var. **umbratilis** Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902.

Lower leaves petiolate, obovate, oblong-ovate to oblong-elliptic, 2 to 8 cm. long, 1.5 to 5.5 cm. broad, petioles 2 to 12 cm. long.

Distribution: occurring occasionally with the species, especially in shady places from Indiana and Virginia to Louisiana.

Specimens examined:

Indiana: without definite locality, *Clapp* (Gray Herb.), TYPE.

Virginia: shaded rocks, Bedford Co., 9 May, 1871, *A. H. Curtiss* (Gray Herb.).

Kentucky: flat wet barrens, Henderson Co., 5 May, 1842, *Short* (Phil. Acad. Nat. Sci. Herb.).

Tennessee: marsh, Jackson, 15 April, 1893, *Bain 421* (Gray Herb.).

Missouri: Monteer, 27 April, 1907, *Bush 4337* (Mo. Bot. Gard. Herb.).

Arkansas: in woods, Fulton, 15 April, 1902, *Bush 1356* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); on low ground, Fulton, 17 April, 1905, *Bush 2355* (Mo. Bot. Gard. Herb.); Judsonia, 15 May, 1877, *Reynolds* (Field Mus. Herb.); Texarkana, 16 May, 1901, *Trelease* (Mo. Bot. Gard. Herb.); without definite locality, *Dr. Pitcher* (Phil. Acad. Nat. Sci. Herb.).

49. S. Cardamine Greene, Bull. Torr. Bot. Club **8**:98. 1881; Gray, Syn. Fl. N. Am. **1**²:390. 1884, and ed. 2, 1886; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902; Wooton & Standley, Contr. U. S. Nat. Herb. **19**:747. 1915.

A low herbaceous perennial, glabrous throughout or slightly tomentulose in the leaf-axils; roots fibrous; stems one to several from a stoutish rootstock, 1 to 3.5 dm. high; leaves mostly radical, petiolate, round-ovate, 1 to 5 cm. long and broad, deeply cordate, crenate, green above, purple-tinged beneath; petioles 2 to 9 cm. long; stem-leaves 1 to 3, more or less amplexicaul, the uppermost sessile and much reduced; heads few, 1 to 3, about 1 cm. high, radiate; involucre campanulate, sparingly calyculate; bracts of the involucre lanceolate, 6 to 8 mm. long; ray-flowers 8 to 10, rays yellow; disk-flowers numerous, achenes glabrous.

Distribution: mountains of southwestern New Mexico.

Specimens examined:

New Mexico: Mogollon Mountains, 25 April, 1881, *Greene* (Gray Herb., Greene Herb., Kew Herb., Torrey Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.), TYPE; Mogollon Mountains, Willow Creek, 8 Aug., 1900, *Wooton* (U. S. Nat. Herb. 739065).

50. S. cyclophyllus Greenm. Field Col. Mus. Bot. Ser. 2:276. 1907.

An herbaceous perennial; stem simple, 3.5 to 5 dm. high, sparingly tawny tomentulose at the base and in the axils of the leaves, otherwise glabrous, striate, somewhat purplish; radical and lowermost stem-leaves subrotund, 4 to 7 cm. long, equally broad, deeply cordate, crenate-dentate, green and glabrous above, purple beneath, petioles 5 to 8 cm. long; upper stem-leaves sessile, amplexicaul, pinnately divided into narrowly obovate-cuneate, unequally dentate lateral divisions and a relatively large subreniform terminal division; inflorescence a terminal many-headed subcorymbose cyme; heads 7 to 9 mm. high, radiate; involucre campanulate, sparingly calyculate with minute bracteoles, glabrous; bracts of the involucre about 21, lance-linear, 5 to 6 mm. long, acute, more or less purple-tipped; ray-flowers about 13, rays yellow; disk-flowers 50 to 60; mature achenes 2 mm. long, hispidulous.

Distribution: northeastern Mexico.

Specimens examined:

Nuevo Leon: near Monterey, coll. of 1906, *Pringle 10230* (Gray Herb., photograph in Field Mus. Herb. and Mo. Bot. Gard. Herb.), TYPE; Cerro la Scilla, near Monterey, 20 March, 1902, *Nelson 6672* (Gray Herb.).

51. S. quebradensis Greenm.[1]

[1]**Senecio quebradensis** Greenm. sp. nov., herbaceus perennis glabrus vel praesertim in axillis foliorum albo-floccosus; caule simplice vel ramoso 1.5–4 dm. alto striato glabro; foliis inferioribus petiolatis rotundo-ovatis vel oblongo-ovatis 1–6 cm. longis, 1–5 cm. latis plerumque cordatis crenato-dentatis utrinque glabris vel juventa parce floccoso-tomentulosis et mox glabratis subinde purpurascentibus; foliis inferioribus plus minusve pinnatisectis et amplexicaulibus; inflorescentiis terminalibus corymboso-cymosis; capitulis paucis vel numerosis 8–10 mm. altis radiatis; involucro campanulato calyculato glabro; bracteis involucri 13–21 lineari-lanceolatis 5–6 mm. longis acutis penicillatis; floseulis liguliferis 8–10, ligulis flavis; floribus disci numerosis; achaeniis valde costatis glabris.—Collected at Quebrada Honda, State of Durango, Mexico, 20 and 21 May, 1906, *Palmer 213* (Gray Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.), TYPE.

An herbaceous perennial, glabrous or white-floccose in the leaf-axils and on the margins of the petioles; stem simple or branched, 1.5 to 4 dm. high from a stout rootstock, striate, glabrous; lower leaves petiolate, round-ovate to ovate-oblong, 1 to 6 cm. long, 1 to 5 cm. broad, usually cordate, crenate-dentate, glabrous on both surfaces or slightly floccose-tomentulose in the early stages but soon glabrate; upper stem-leaves more or less pinnatisect and amplexicaul; inflorescence a subcorymbose cyme terminating the stem and branches, few to many-headed; heads 8 to 10 mm. high, radiate; involucre campanulate, calyculate, glabrous; bracts of the involucre 13 to 21, linear-lanceolate, attenuate, 5 to 6 mm. long; ray-flowers 8 to 10, rays pale yellow; disk-flowers rather numerous; achenes strongly ribbed, glabrous.

Distribution: western Mexico.

Specimens examined:

Durango: Quebrada Honda, 20–21 May, 1906, *Palmer 213* (Gray Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.), TYPE.

52. S. Pammelii Greenm.[1]

An herbaceous perennial, glabrous or slightly white-tomentulose in the axils of the leaves; stems erect, 2 to 4 dm. high, and, as well as the petioles, more or less purplish towards the base; lower leaves long-petiolate, rotund-ovate, 1 to 2.5 cm. long, nearly or quite as broad, shallowly cordate or subtruncate, crenate to nearly entire; upper stem-leaves petiolate and somewhat lyrate to sessile and pinnatisect to entire; inflo-

[1]**Senecio Pammelii** Greenm. sp. nov., herbaceus perennis ubique glabrus vel in axillis foliorum paululo albo-tomentulosus; caulibus erectis 2–4 dm. altis ad basin petiolis etiam plus minusve purpurascentibus; foliis inferioribus longi-petiolatis rotundo-ovatis 1–2.5 cm. longis et latis brevi-cordatis vel subtruncatis crenatis vel fere integris; foliis superioribus petiolatis et sublyratis vel sessilibus et pinnatisectis; inflorescentiis corymboso-cymosis; capitulis 7–10 mm. altis paucis vel pluribus radiatis; involucro campanulato calyculato; bracteis involucri 13–21 lineari-lanceolatis 5–6 mm. longis acutis glabris; flosculis liguliferis 10–12, ligulis flavis; floribus disci numerosis; achaeniis glabris.—Collected in Peterson Cañon, Peterson, Utah, alt. 2895 m., 19 July, 1902, *Pammel & Blackwood 387* (Mo. Bot. Gard. Herb.), TYPE; on Ruby Mountains, near Blaine post-office, Elko Co., Nevada, alt. 2710 m., 27 Aug., 1913, *Heller 11096* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.).

This species may be looked for in herbaria under *S. aureus*, also under *S. rubricaulis* having been distributed under both names.

rescence a few to many-headed corymbose cyme; involucre campanulate, sparingly calyculate; heads 7 to 10 mm. high, radiate; bracts of the involucre 13 to 21, linear-lanceolate, 5 to 6 mm. long, acute, glabrous; ray-flowers 10 to 12, rays bright yellow; disk-flowers numerous; achenes glabrous.

Distribution: mountains of Utah and Nevada.

Specimens examined:

Utah: moist rocks and shady woods, Peterson Cañon, Peterson, alt. 2895 m., 19 July, 1902, *Pammel & Blackwood 3870* (Mo. Bot. Gard. Herb.), TYPE.

Nevada: Ruby Mountains, near Blaine post-office, Elko Co., alt. 2710 m., 27 Aug., 1913, *Heller 11096* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.).

53. S. aureus L. Sp. Pl. **2**:870. 1753, ed. 2, 1220. 1763, and ed. 3, 1220. 1764; Michx. Fl. **2**: 120. 1803; Willd. Sp. Pl. **3**:1998. 1804; Pursh, Fl. Am. Sept. **2**:530. 1814, and ed. 2, 1816; Nutt. Gen. **2**:165. 1818; Ell. Sketch **2**:331. 1824; Bigel. Fl. Bost. 307. 1824; Sprengl, Syst. Veg. **3**:560. 1826, excl. syn.; DC. Prodr. **6**:432. 1837; Torr. & Gray, Fl. N. Am. **2**:442. 1843, in part; Torr. in Nicollet's Report, App. B, 153 [237]. 1843; Gray, Syn. Fl. N. Am. **1**²:391. 1884, and ed. 2, 1886, in part; Macoun, Cat. Canadian Pl. 264. 1884, in part; Millsp. Med. Pl. **1**:91, *pl. 91.* 1892; Goodale, Wild Fls. of Am. 77, *pl. 15.* 1894; Britton & Brown, Ill. Fl. **3**:480, *fig. 4047.* 1898, and ed. 2, 544, *fig. 4625.* 1913, in part; Greenm. in Rhodora **3**:4. 1901; Monogr. Senecio, I. Teil, 23. 1901, and in Engl. Bot. Jahrb. **32**:19. 1902; Britton, Manual 1028. 1901, and ed. 2, 1905; Greenm. in Gray, Manual, ed. 7, 854. 1908; Small & Carter, Fl. Lancaster County 310. 1913.

S. tussilaginoides Walt. Fl. Carol. 208. 1788.

S. rotundifolius Stokes, Bot. Mat. Med. **4**:215. 1812.

S. fastigiatus Schwein. ex Ell. Sketch **2**:331. 1824.

An herbaceous perennial; stems one to several from a relatively slender rootstock, 3 to 6 dm. high, glabrous or not infrequently white-tomentulose in the leaf-axils, along the margins of the petioles, and in the inflorescence; lower leaves petiolate, undivided and rotund-ovate, somewhat triangular-ovate to

oblong-ovate, 1 to 14 cm. long, two-thirds to nearly or quite as broad, crenate to doubly serrate-dentate, usually deeply cordate at the base, green on both surfaces or tinged with purple beneath, glabrous or occasionally slightly tomentulose in the early stages and soon glabrate; petioles 1.5 to 25 cm. long; stem-leaves variable, petiolate to sessile and amplexicaul, lyrate to pinnatisect, reduced towards the inflorescence sometimes to linear entire bracts; inflorescence a terminal several to many-headed corymbose cyme; heads 8 to 10 mm. high, radiate; involucre campanulate, calyculate, glabrous or occasionally slightly tomentulose; bracts of the involucre (13–) 21, linear, acute, 6 to 8 mm. long; ray-flowers 8 to 12, rays yellow; disk-flowers numerous; achenes glabrous.

Distribution: Labrador to Georgia, and west to North Dakota and Arkansas.

Specimens examined.

Labrador: shore of Seal Lake, 3 Aug., 1896, *Spreadborough 14387* (Geol. Surv. Canada Herb.).

Newfoundland: north of Placentia Junction, 11 Aug., 1894, *Robinson & Schrenk* (Gray Herb. and U. S. Nat. Herb.); banks of Salmonier River, 21 Aug., 1894, *Robinson & Schrenk* (Gray Herb., Geol. Surv. Canada Herb., and U. S. Nat. Herb.); Benoist's Cove, Bay of Islands, July, 1895, *Waghorne* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); between Port-aux-Basques and Bay of Islands, July, 1902, collector not indicated (Gray Herb.).

Prince Edward Island: wet meadows, Tignish, 27 July, 1888, *Macoun 14812* (Geol. Surv. Canada Herb.).

Nova Scotia: Arcadia, Yarmouth Co., 29 June, 1911, *Metheny* (Phil. Acad. Nat. Sci. Herb.).

New Brunswick: swamps, Tobique, July, 1884, *Hay 14817* (Geol. Surv. Canada Herb.); along the St. John River, above Woodstock, 3 July, 1899, *Macoun 22537* (Geol. Surv. Canada Herb.).

Quebec: damp thickets, Lake Mistassini, 24 July, 1885, *Macoun 14819* (Geol. Surv. Canada Herb.); Fort Chimo, on the Ungava River, 31 Aug., 1896, *Spreadborough 14386*

(Geol. Surv. Canada Herb.); in swamps and marshes, Anticosti Island, 20 Aug., 1883, *Macoun 14816* (Geol. Surv. Canada Herb.); swamps and sandy woods, River Ste. Anne des Monts, Gaspé, 19 Aug., 1882, *Macoun 14821* (Geol. Surv. Canada Herb.); banks of Grand River, Gaspé Co., 30 June–3 July, 1904, *Fernald* (Gray Herb.); calcareous alpine meadow, Table-top Mountain, Gaspé Co., alt. 1000–1125 m., 7 Aug., 1906, *Fernald & Collins 260* (U. S. Nat. Herb.); coniferous forest, Low's Trail from the Forks of River Ste. Anne des Monts to Table-top Mountain, Gaspé Co., alt. 550 m., *Fernald & Collins 765*, *766*, and *767* (Gray Herb.); mossy arbor-vitae woods, east of Grande Coupe, Percé, Gaspé Co., 6 Aug., 1907, *Fernald & Collins 1208* (Gray Herb.); alluvial woods, mouth of Bonaventure River, Bonaventure Co., 31 July, 1902, *Williams & Fernald* (Gray Herb.); wet alluvial shores, gravelly beaches and flats, between Baldé and the Baie des Chaleurs, Bonaventure River, 5–8 Aug., 1904, *Collins, Fernald & Pease* (Gray Herb.); alluvial thickets, between the Forks and Brûle Brook, Little Cascapedia River, 29 and 30 July, 1904, *Collins, Fernald & Pease* (Gray Herb.).

Ontario: in a bog, Rainy Lake, Algonquin Park, 12 June, 1900, *Macoun 21869* (Geol. Surv. Canada Herb.); river banks, Inglewood, 4 July, 1890, *White 14823* (Geol. Surv. Canada Herb.); swamps and sandy woods, Kammistiquia River, 13 July, 1869, *Macoun 14814* (Geol. Surv. Canada Herb.); Glen Elgin, Lincoln Co., 10 June, 1897, *McCalla 662, 22779* (Geol. Surv. Canada Herb.); swamps above Leamington, 30 May, 1901, *Macoun 26671* (Geol. Surv. Canada Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); London, June, 1884, *Burgess* (U. S. Nat. Herb.); Amherstburg, 9 June, 1882, *Macoun 14813* (Geol. Surv. Canada Herb.).

Maine: wet thickets, Limestone, Aroostook Co., 20 June, 1898, *Fernald 2403* (Gray Herb.); arbor-vitae swamp, Presque Isle, 12 July, 1902, *Williams, Collins & Fernald* (Gray Herb.); cedar swamp and clearings, Blaine, 23 June, 1898, *Fernald 2404* (Gray Herb.).

New Hampshire: Greenville, 6 June, 1897, *Fernald* (Gray Herb.); sphagnum bog, Jaffrey, 10 July, 1897, *Robinson 590* (Gray Herb.).

Vermont: Peacham, 1 July, 1888, *F. Blanchard* (Mo. Bot. Gard. Herb.); Brandon, 8 June, 1883, *Knowlton* (U. S. Nat. Herb.); Castleton, 3 June, 1898, *Eggleston* (Mo. Bot. Gard. Herb.); Windham, 25 July, 1901, *W. H. Blanchard* (Gray Herb.); Manchester, 27 June, 1898, *Day 102* (Gray Herb. and U. S. Nat. Herb.).

Massachusetts: Hamilton, Essex Co., *Oakes* (Gray Herb.); near Boston, 13 June, 1854, *ex Herb. Wm. Boot* (Gray Herb.); without definite locality, *Pickering* (Phil. Acad. Nat. Sci. Herb.); Boston, *ex Herb. Short* (Phil. Acad. Nat. Sci. Herb.); Arlington Heights, 5 June, 1904, *Greenman 3005* (Mo. Bot. Gard. Herb.); Concord, 30 May, 1896, *Greenman 305* (Mo. Bot. Gard. Herb.); Purgatory Swamp, Dedham, 30 May, 1897, *Greenman 280* (Mo. Bot. Gard. Herb.); Holbrook, 18 June, 1899, *Greenman 609* (Mo. Bot. Gard. Herb.); South Framingham, 18 May, 1890, *Sturtevant* (Mo. Bot. Gard. Herb.); Nonquitt, 21–30 May, 1889, *Sturtevant* (Mo. Bot. Gard. Herb.); Southampton, *ex Herb. Chapman* (Mo. Bot. Gard. Herb.).

Rhode Island: Monns Swamp, Providence, 24 May, 1891, *Collins* (Gray Herb.); Providence, coll. of 1846, *Thurber* (Gray Herb.), 10 June, 1900, *Chamberlain 154* (U. S. Nat. Herb.), and without date, *Olney* (Kew Herb.).

Connecticut: Southington, 30 May, 1896, *Andrews 4* (Gray Herb.), 25 May, 1897, *Bissell 112, 1480* (Mo. Bot. Gard. Herb.); Waterbury, 3 June, 1888, *Du Bois* (U. S. Nat. Herb.); New Haven, without date, *Eaton* (Gray Herb.); near Maltby Park, New Haven, 28 May, 1884, *Safford 85* (U. S. Nat. Herb.); Bridgeport, 25 May, 1896, *Eames* (U. S. Nat. Herb.).

New York: Lebanon Springs, 31 May, 1898, *Harrison 8* (U. S. Nat. Herb.); vicinity of North Harpersfield, Delaware Co., June, 1906, *Topping 69, 103, 106* (U. S. Nat. Herb.); vicinity of Oneida, June–July, 1914, *Maxon* (U. S. Nat. Herb.); near Syracuse, *Straub* (U. S. Nat. Herb.); Ithaca, 3 and 21 June, 1885, *Coville*, 21 June, 1889, *Pearce*, and 31

May, 1890, *Rowlee* (U. S. Nat. Herb.); near Ithaca, coll. of 1889, *Norris* (Mo. Bot. Gard. Herb.); Cascadilla Creek, 6 June, 1877, *Trelease* (Mo. Bot. Gard. Herb.); Fall Creek, 14 June, 1893, *Schrenk* (Mo. Bot. Gard. Herb.); western New York, collector and date not indicated (Gray Herb.); Clove Lake, Staten Island, 28 May, 1905, *Dowell 3764* (Mo. Bot. Gard. Herb.).

New Jersey: New Durham, *Brownne* (Kew Herb.); Tenafly, 26 May, 1894, *Pollard* (U. S. Nat. Herb.); Fairview, 23 May, 1895, *Van Sickle* (U. S. Nat. Herb.); Charlotteburg, 24 May, 1908, *Mackenzie 3085* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Newfoundland, 14 June, 1908, *Mackenzie 3127* (U. S. Nat. Herb.); Mt. Tabor, 16 June, 1907, *Mackenzie 2640* (Mo. Bot. Gard. Herb.); Budd's Lake, 28 May, 1895, *Heritage* (Phil. Acad. Nat. Sci. Herb.); Bound Brook, 31 May, 1904, *House* (U. S. Nat. Herb.); river bank above Crosswick's Creek, 29 May, 1904, *Williamson* (C. S. Williamson Herb.); Batsto, 22 May, 1912, *Bassett 17* (Phil. Acad. Nat. Sci. Herb.); shore of Delaware River, Camden Co., 10 May, 1910, *Long 3259* (Phil. Acad. Nat. Sci. Herb.); Washington Park, 9 May, 1897, *Jahn* (Phil. Acad. Nat. Sci. Herb.); below Washington Park, 15 May, 1895, *Jahn* (Phil. Acad. Nat. Sci. Herb.); Glassboro, 14 May, 1910, *Long 3346* (Phil. Acad. Nat. Sci. Herb.); Bennett, 29 Oct., 1912, *Long 7954* (Phil. Acad. Nat. Sci. Herb.); without locality or date, *Read* (Phil. Acad. Nat. Sci. Herb.).

Pennsylvania: Milford, May, 1905, *Mell* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Tobyhanna Mills, 3 July, 1893, *Crawford* (Phil. Acad. Nat. Sci. Herb.); in deep shaded bog, Tobyhanna, 27 July, 1907, *Bartram* (Phil. Acad. Nat. Sci. Herb.); bog near Easton, 18 May, 1894, *Tyler* (Phil. Acad. Nat. Sci. Herb.); Hellertown, *ex Herb. Detwillert* (Phil. Acad. Nat. Sci. Herb.); streamlet east of Slatington reservoir, 2 June, 1912, *Pretz 4512* (Phil. Acad. Nat. Sci. Herb.); Threemile Run, 21 May, 1886, *Fretz* (Phil. Acad. Nat. Sci. Herb.); Rock Hill, 2 June, 1889, *Pollard* (U. S. Nat. Herb.); Sellersville, June, 1887, *Fretz* (Phil. Acad. Nat. Sci. Herb.); Doyles-

town, 18 May, 1883, *Pond* (U. S. Nat. Herb.); Woodbourne, 30 May, 1904, *Brown* (Phil. Acad. Nat. Sci. Herb.); Tullytown, 30 May, 1899, *Williamson* (C. S. Williamson Herb.); Tullytown, 3 May, 1899, *Crawford* (Phil. Acad. Nat. Sci. Herb.); Tullytown, 20 May, 1899, *Fretz* (Phil. Acad. Nat. Sci. Herb.); Bucks Co., coll. of 1867, *Allen* (Phil. Acad. Nat. Sci. Herb.); Shannonville, 12 June, 1891, *Crawford* (Phil. Acad. Nat. Sci. Herb.); Arcola, 6 May, 1892, *Crawford* (Phil. Acad. Nat. Sci. Herb.); Merion, 25 April, 1871, *Redfield* (Mo. Bot. Gard. Herb.); French Creek Falls, *MacElwee* (Phil. Acad. Nat. Sci. Herb.); Darby Creek, near Paoli, 21 May, 1905, *Bartram* (Phil. Acad. Nat. Sci. Herb.); Westtown Meadow, 7 May, 1890, *N. H. C.* (Phil. Acad. Nat. Sci. Herb.); near Pocopson, 27 May, 1904, *Painter 628* (Mo. Bot. Gard. Herb.); near Brandywine, *Townsend* (Phil. Acad. Nat. Sci. Herb.); New Garden, 29 May, 1904, *Vanatta* (Phil. Acad. Nat. Sci. Herb.); Haverford, *D. B. Smith* (Kew Herb.); west side of Wissahickon River, 18 June, 1834, collector not indicated (Phil. Acad. Nat. Sci. Herb.); West Philadelphia, 4 May, 1890, *MacElwee 475* (Phil. Acad. Nat. Sci. Herb.); Crum Creek, near Philadelphia, 6 June, 1867, *Redfield* (Mo. Bot. Gard. Herb.); Crum Creek, 30 May, 1898, *Githens* (Phil. Acad. Nat. Sci. Herb.); Byberry, coll. of 1862, *Martindale* (Phil. Acad. Nat. Sci. Herb.); near Mickelton, 14 May, 1892, *Heritage* (Phil. Acad. Nat. Sci. Herb.); Delaware Co., 10 May, 1891, *MacElwee* (Phil. Acad. Nat. Sci. Herb.); Clifton, 7 May, 1893, *Lloyd* (Phil. Acad. Nat. Sci. Herb.); Dillerville swamp, Lancaster Co., 30 May, 1901, *Heller* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); on Little Conestoga near Stoneroad's Mill, 23 May, 1901, *Heller* (Gray Herb. and U. S. Nat. Herb.); between York Furnace and Tucquam, 11 May, 1901, *Heller* (Gray Herb. and U. S. Nat. Herb.); Fishing Creek, 16 May, 1906, *Carter* (Phil. Acad. Nat. Sci. Herb.); west branch of Octoraro Creek, 6 May, 1891, *Small & Heller* (U. S. Nat. Herb.); York Furnace, York Co., 13 May, 1899, *MacElwee 201* (Phil. Acad. Nat. Sci. Herb.); Meadow-ground Mountain, Fulton Co., 4 June, 1905, *Stone 226* (Phil. Acad.

Nat. Sci. Herb.); Mt. Alto, coll. of 1900, *Illick* (Mo. Bot. Gard. Herb.).

Delaware: Granogue, 27 May, 1896, *Commons* (Phil. Acad. Nat. Sci. Herb.); near Centerville, 26 May, 1875, *Commons* (Phil. Acad. Nat. Sci. Herb.); Green Bank, 12 May, 1884, *Commons* (Phil. Acad. Nat. Sci. Herb.); Elsmere, 14 May, 1894, *Commons* (Phil. Acad. Nat. Sci. Herb.); west branch of Naaman's Creek, 15 May, 1909, *Pennell 2040* (Phil. Acad. Nat. Sci. Herb.).

Maryland: along the Susquehanna River, Cecil Co., 18 April, 1913, *St. John & Long 8076* (Phil. Acad. Nat. Sci. Herb.); Calreston, 5 May, 1889, *Thurston* (U. S. Nat. Herb.); near Great Falls, Montgomery Co., 18 May, 1900, *M. F. Miller* (U. S. Nat. Herb.); Plummer's Island, near Cabin John, 30 April, 1902, *Kearney & Maxon* (U. S. Nat. Herb.); Montgomery Co., near Washington, *Batchelder* (Phil. Acad. Nat. Sci. Herb.); Marlboro, 6 May, 1900, *Morris 914* (U. S. Nat. Herb.); Savage River, Garrett Co., 25 April, 1897, *Knowlton* (U. S. Nat. Herb.).

District of Columbia: Washington, coll. of 1873, *Vasey* (U. S. Nat. Herb.); High Island, 2 April, 1876, *Ward* (U. S. Nat. Herb.); vicinity of Washington, 10 June, 1877, *Ward* (U. S. Nat. Herb.); without definite locality, 29 April, 1888, *Burgess* (U. S. Nat. Herb.); National Park, 6 May, 1892, *F. Blanchard* (Mo. Bot. Gard. Herb.); Glen Echo, 24 April, 1895, *Pollard 89* (U. S. Nat. Herb.); Rock Creek Park, 4 May, 1896, *Steele* (Gray Herb. and U. S. Nat. Herb.); High Island, April, 1898, *Williamson* (C. S. Williamson Herb.); pine woods, Dalecartia Reservoir, 23 May, 1905, *Painter 1305* (Mo. Bot. Gard. Herb.); Chevy Chase, 16 May, 1905, *House 728* (Mo. Bot. Gard. Herb.).

Virginia: Arlington, April, 1891, *F. Blanchard* (Mo. Bot. Gard. Herb.); Stony Man Mountain, 3 July, 1903, *G. S. Miller* (U. S. Nat. Herb.); on Bear Creek, east of Hungry Hollow, Smyth Co., alt. 830 m., 7 June, 1892, *Small* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); about Chatham Hill Gap, Walker Mountain, alt. 915 m., *Small* (Gray Herb.); Walker Mountain,

alt. 640 m., *E. G. Britton & A. M. Vail* (Phil. Acad. Nat. Sci. Herb.).

North Carolina: Cloudland, Roan Mountain, 25 June, 1902, *Cannon 10* (U. S. Nat. Herb.); vicinity of Asheville, May, 1888, *McCarthy* (U. S. Nat. Herb.); Biltmore, 24 April, 1896, and 13 April, 1897, *Biltmore Herb. 889, 889a* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); mountains of North Carolina, *Ashe* (U. S. Nat. Herb.).

Georgia: without locality, *ex Herb. Chapman 2340* (Mo. Bot. Gard. Herb.).

West Virginia: Upshur Co., 4 May, 1895, and 27 May, 1897, *Pollock* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.).

Ohio: Berea, May, 1895, *Ashcroft* (Mo. Bot. Gard. Herb.); Canton, May, 1835, *Riehl* (Mo. Bot. Gard. Herb.); Columbus, *Sullivant* (Kew Herb.); Champaign Co., 27 May, 1893, *Werner 138* (Gray Herb.).

Michigan: Port Huron, 18 May, 1896, *Dodge 296* (U. S. Nat. Herb.); moist rich woods and river banks, Rochester, May, 1914, *Farwell 3384, 3628½*, and at Parkdale Farms, colls. of May and June, 1912, 1913, *Farwell 2552, 3408, 3425* (Mo. Bot. Gard. Herb.); Owosso, 21 May, 1889, *Hicks* (U. S. Nat. Herb.).

Indiana: Chain Lakes, 6 May, 1913, *Nieuwland 11005* (Mo. Bot. Gard. Herb.); Mineral Springs, 20 May, 1912, *Nieuwland 10019* (Mo. Bot. Gard. Herb.); bank of Wabash River, west of Shively Bridge, 19 May, 1901, *Mackenzie* (U. S. Nat. Herb.); West Lafayette, 10 May, 1912, *Overholts* (Mo. Bot. Gard. Herb.); Jefferson Co., *Hubbard* (Gray Herb.); banks of Lick Creek near Abby Dell, 25 May, 1901, *Mackenzie* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.).

Kentucky: Blue-licks and Mud-lick, *Short* (Phil. Acad. Nat. Sci. Herb.); Bowling Green, May, 1892, *Price* (Mo. Bot. Gard. Herb.).

Illinois: in moist rich thickets and wet meadows near Beach, 16 June, 1907, *Greenman 2007, 2022, 2023* (Mo. Bot. Gard. Herb.); near Woodlawn, Jefferson Co., 16 May, 1898, *Eggert* (Mo. Bot. Gard. Herb.).

Minnesota: Bear Creek, May, 1890, *Holzinger* (U. S. Nat. Herb.).

South Dakota: Brookings, coll. of 1892, *Williams* (U. S. Nat. Herb.); along creeks, Brookings, 26 May, 1894, *Thornber* (Mo. Bot. Gard. Herb.); low ground, Oakwood, 23 May, 1902, *A. G. J.* (Mo. Bot. Gard. Herb.); Custer Co., alt. 1675 m., 16 July, 1892, *Rydberg 827* (Gray Herb.), in part.

Nebraska: Emerson, 12 June, 1893, *Clements 2513* (U. S. Nat. Herb.).

Iowa: Iowa City, *Hitchcock* (Mo. Bot. Gard. Herb.); prairies, near Council Bluffs, Nicollet's North-Western Expedition, 16 May, 1839, *Geyer 97* (Gray Herb., U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.).

Missouri: low ground, Adair Co., 5 May, 1884, *Sheldon* (Mo. Bot. Gard. Herb.); Courtney, coll. of 1880, *Bush* (U. S. Nat. Herb.); banks of River des Peres, near St. Louis, May, 1883, *Engelmann* (Mo. Bot. Gard. Herb.); "Valley Forge", 11 May, 1888, *Pammel* (Mo. Bot. Gard. Herb.); Glencoe, 22 May, 1879, *Eggert* (Mo. Bot. Gard. Herb.); Allenton, April, 1890, *Letterman* (Mo. Bot. Gard. Herb.); Allenton, 23 May, 1892, *Glatfelter 293* (Mo. Bot. Gard. Herb.); Cliff Cave, 26 Aug., 1898, *Norton* (Mo. Bot. Gard. Herb.); Pacific, 4 July, 1879, *Eggert* (Mo. Bot. Gard. Herb.); Pacific, 15 May, 1900, *Norton* (Mo. Bot. Gard. Herb.); Victoria, 10 May, 1890, *Hitchcock* (Mo. Bot. Gard. Herb.); near Sunnyside, 22 May, 1879, *Eggert* (Mo. Bot. Gard. Herb.); De Soto, 22 May, 1892, *Eggert* (Mo. Bot. Gard. Herb.); Valles Mines, May, 1835, *(?)Engelmann* (Mo. Bot. Gard. Herb.); Shannon Co., coll. of 1890, *Bush* (U. S. Nat. Herb.); Monteer, 24 May, 1900, *Bush 370* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); along streams, Monteer, 14 May, 1901, and 29 April, 1907, *Bush 465, 4395* (Mo. Bot. Gard. Herb.); Greene Co., 30 May, 1879, *Shepard* (Gray Herb.); Swan, Taney Co., 21 April, 1907, *Bush 4225* (Mo. Bot. Gard. Herb.); Galena, Stone Co., 3 May, 1914, *E. J. Palmer 5743* (Mo. Bot. Gard. Herb.); Reding's Mill, 9 April, 1909, *E. J. Palmer 1655* (Mo. Bot. Gard. Herb.).

Arkansas: Eureka Springs, Carroll Co., 15 May, 1914, *E. J. Palmer 5623* (Mo. Bot. Gard. Herb.); northwestern Arkansas, April, 1880, *Harvey 45* (Gray Herb.).

Var. **gracilis** (Pursh) Britt. in Britton & Brown, Ill. Fl. 3:481. 1898; Britton, Manual 1028. 1901, and ed. 2, 1905; Greenm. Monogr. Senecio, I. Teil, 23. 1901, in Engl. Bot. Jahrb. 32:19. 1902, and in Gray, Manual, ed. 7, 854. 1908; Porter, Fl. Penn. 339. 1903.

S. gracilis Pursh, Fl. Am. Sept. 2:529. 1814, and ed. 2, 1816; DC. Prodr. 6:432. 1837; Small, Fl. Southeastern U. S. 1303. 1903, and ed. 2, 1913.

Stems slender; basal leaves relatively small, those of the offshoots, as well as the lower stem-leaves, rotund-ovate to oblong-ovate, 1 to 2 cm. long and nearly to quite as broad. In all other essential characters like the species into which it directly passes.

Distribution: occurring with the species, but especially in moist open places.

Specimens examined:

Ontario: Squirrel Island, 10 June, 1904, *Dodge 14, 297a* (U. S. Nat. Herb.).

New Jersey: Point Pleasant, *Williamson* (C. S. Williamson Herb.); meadows, etc., New Egypt, 14 May, 1906, *Grove 315* (Phil. Acad. Nat. Sci. Herb.); Spray, *de Chalmot* (U. S. Nat. Herb.); Swedesboro, 15 May, 1892, *Lippincott* (Phil. Acad. Nat. Sci. Herb.).

Pennsylvania: Wayne, 2 May, 1908, *Bartram* (Phil. Acad. Nat. Sci. Herb.); Lehigh Co., *Pretz 345, 4398, 3272, 6483, 6457* (Phil. Acad. Nat. Sci. Herb.); Bucks Co., coll. of 1860, *Krout* (Phil. Acad. Nat. Sci. Herb.); Nockamixon, coll. of 1893, *Crawford* (Phil. Acad. Nat. Sci. Herb.); near Quakertown, 9 May, 1899, *Fretz* (Phil. Acad. Nat. Sci. Herb.); Rock Hill, 31 May, 1903, *MacElwee* (Phil. Acad. Nat. Sci. Herb.); Tohickon Creek near Doylestown, 30 May, 1902, *Brown* (Phil. Acad. Nat. Sci. Herb.); meadows along Wissahickon Creek, Fort Washington, 7 May, 1909, *Long* (Phil. Acad. Nat. Sci. Herb.); near Ardmore, 15 May, 1909, *Eckfeldt* (Phil. Acad. Nat. Sci. Herb.); near Tredyffrin, 6 May, 1906, *Bartram* (Phil. Acad. Nat. Sci. Herb.); Chester Heights, 9 May, 1909, *Pennell 2030* (Phil. Acad. Nat. Sci. Herb.); Dillerville Swamp,

Lancaster Co., 25 May, 1889, *Heller* (Gray Herb.); New Providence, 18 May, 1900, *Heller* (Mo. Bot. Gard. Herb.); about Penryn, Lebanon Co., 27 May, 1893, *Heller & Halbeck 876* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.).

Delaware: west branch of Naaman's Creek, 15 May, 1909, *Pennell 2044* (Phil. Acad. Nat. Sci. Herb.); near Cooch's Mill, 29 May, 1896, *Commons* (Phil. Acad. Nat. Sci. Herb.).

Maryland: near Great Falls, 8 May, 1895, *Mearns* (U. S. Nat. Herb.).

District of Columbia: Carberry Meadows, 7 May, 1903, *Steele* (Mo. Bot. Gard. Herb.).

Michigan: marl beds on Parkdale Farm, 25 May, 1913, *Farwell 3415* (Mo. Bot. Gard. Herb.); in wet meadows, Grand Rapids, 17 May, 1894, and 26 June, 1897, *Cole* (Gray Herb.).

Illinois: Palos Park, 22 May, 1913, *Millspaugh 3744* (Field Mus. Herb.).

Minnesota: Fort Snelling, coll. of 1888, *Forwood,* also 1 and 14 June, 1891, *Mearns* (U. S. Nat. Herb.); Nicollet, June, 1892, *Ballard* (U. S. Nat. Herb.).

North Dakota: in bogs, Butte, 3 June, 1906, *Lunell* (U. S. Nat. Herb.).

Var. **semicordatus** (Mack. & Bush) Greenm. comb. nov.

S. semicordatus Mack. & Bush, Mo. Bot. Gard. Ann. Rept. **16**:107. 1905.

S. aureus Mack. & Bush, Manual Fl. Jackson County, Mo. 207. 1902, in part, not L.

S. aureus> × *Balsamitae* Greenm. Rhodora **10**:69. 1908.

Lower leaves rotund-ovate to oblong-ovate, 1 to 8 cm. long, 1 to 4 cm. broad, usually rounded at the apex, shallowly cordate.

Distribution: beaches, shores, and prairies. Eastern Quebec, Illinois, and Missouri.

Specimens examined:

Quebec: wet alluvial shores, gravelly beaches and flats, between Baldé and the Baie des Chaleurs, Bonaventure River, 5, 6, and 8 Aug., 1904, *Collins, Fernald & Pease* (Gray Herb., photograph in Field Mus. Herb. and Mo. Bot. Gard. Herb.).

Illinois: in wet meadows near Beach, Lake Co., 16 June, 1907, *Greenman 2022* (Field Mus. Herb., photograph in Mo. Bot. Gard Herb.), in part; low ground, Evanston, *Earl*, also *Price* (U. S. Nat. Herb.).

Missouri: on prairies, Levasy, Jackson Co., 18 May, 1902, *Bush 1678* (Gray Herb. and Mo. Bot. Gard. Herb.), TYPE: swales on prairies, Levasy, 11 May, 1904, *Bush 1940* (Mo. Bot. Gard. Herb.).

Although some of the specimens cited show indications of a possible origin by hybridization, as was indicated in 'Rhodora' in 1908, yet the examination of additional material points rather towards an origin by variation.

54. S. Robbinsii Oakes ex Rusby, in Bull. Torr. Bot. Club **20**:19, *pl. 139*. 1893; Heller, Cat. N. Am. Pl. 147. 1898, and ed. 2, 230. 1900; Britton & Brown, Ill. Fl. **3**:480, *fig. 4046*. 1898, and ed. 2, 544, *fig. 4624*. 1913; Greenm. in Rhodora **3**:4. 1901; Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902; Small, Fl. Southeastern U. S. 1303. 1903, and ed. 2, 1913; Kennedy in Rhodora **6**:133. 1904; Britton, Manual 1028. 1901, and ed. 2, 1905; Greenm. in Gray, Manual, ed. 7, 854. 1908.

S. aureus var. *lanceolatus* Oakes ex Torr. & Gray, Fl. N. Am. **2**:442. 1843; Macoun, Cat. Canadian Pl. 265. 1884.

S. aureus var. *Balsamitae* Gray, Syn. Fl. N. Am. **1**²:391. 1884, and ed. 2, 1886, in part, as to *S. aureus* var. *lanceolatus* Oakes in synonymy.

An herbaceous perennial, glabrous or slightly tomentose along the margins of the petioles of the leaves, especially near their sheathing base; lower leaves long-petiolate, ovate-rotund to oblong-lanceolate, 1 to 10 cm. long, 1 to 3 cm. broad, crenate to sharply and more or less serrate-dentate, cordate to abruptly narrowed at the base, green and glabrous on both surfaces; upper stem-leaves petiolate and sublyrate or sessile and more or less pinnatisect; inflorescence a terminal several to many-headed corymbose cyme; heads 8 to 10 mm. high, radiate; involucre campanulate, calyculate; bracts of the involucre about 21, linear, acute, glabrous; ray-flowers 10 to 12, rays yellow; disk-flowers numerous; achenes glabrous.

Distribution: Nova Scotia and Quebec, south to northern New England and New York; also on Roan Mt., North Carolina.

Specimens examined:

Nova Scotia: Margaree, Big Intervale, Cape Breton Island, 19 July, 1898, *Macoun 19717* (Geol. Surv. Canada Herb.); Baddeck, Cape Breton Island, 10 July, 1898, *Macoun 19718* (Geol. Surv. Canada Herb.); Boylston, July, 1890, *Hamilton 22333* (Geol. Surv. Canada Herb.); in swamps and ditches, Truemanville, 30 July, 1883, *Trueman 14773* (Geol. Surv. Canada Herb.); railroad ditch, Truro, 27 July, 1911, *Bartram* (Phil. Acad. Nat. Sci. Herb.).

Prince Edward Island: rocky places, Winslow Road, 16 July, 1888, *Macoun 14794* (Geol. Surv. Canada Herb.).

Quebec: swamp near Georgeville, Lake Memphremagog, 12 July, 1902, *Churchill* (Gray Herb.).

Maine: dry thicket, Van Buren, 24 July, 1893, *Fernald* (Gray Herb.); open swampy woods, Aroostook Co., *Mackenzie 3633* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); damp thickets, Cutler, 5 June, 1902, *Kennedy, Williams, Collins & Fernald* (Gray Herb.); wet meadow, Fitzgerald Pond, near Moosehead Lake, 6 July, 1895, *Fernald 272* (Gray Herb., U. S. Nat. Herb., Greene Herb., and Mo. Bot. Gard. Herb.); meadow near High Head, Mt. Desert, 1 July, 1891, *Redfield* (Phil. Acad. Nat. Sci. Herb. and Mo. Bot. Gard. Herb.); Winthrop, coll. of 1862, *Sturtevant* (Mo. Bot. Gard. Herb.); Hartford, June, 1885, and July, 1892, *Parlin* (Gray Herb.); Westbrook, July, 1900, *Ricker 672* (U. S. Nat. Herb.).

New Hampshire: new gate of Notch, White Mountains, 7 July, 1878, *E. & C. E. Faxon* (Gray Herb.); Crawford Notch, 1 July, 1898, *Greenman 1105* (Gray Herb. and Mo. Bot. Gard. Herb.); wet meadow, Glen House, 10 July, 1910, *Williamson 1421* (C. S. Williamson Herb.); Jackson, 26 July, 1890, *Churchill* (U. S. Nat. Herb.); Jackson, 10 Sept., 1896, *Purdie* (Gray Herb.); Llandoff Valley Meadows, Franconia, 18 June, 1895, *E. & C. E. Faxon* (Gray Herb. and U. S. Nat. Herb.); cedar swamp, Franconia, 19 June, 1895, *E. & C. E. Faxon* (Gray Herb.).

Vermont: cedar swamp, Willoughby Lake, 26 July, 1885, *Deane* (Gray Herb.); Willoughby Mountain, 15 July, 1906, *Williamson* (C. S. Williamson Herb.); Stowe, July, 1899, *Churchill & Greenman 294* (Mo. Bot. Gard. Herb.); Peacham, July, 1892, *F. Blanchard* (Mo. Bot. Gard. Herb.); Starksboro, 10 June, 1898, *Eggleston* (Mo. Bot. Gard. Herb.); Middlebury, 23 and 25 June, 1883, *Brainerd* (Gray Herb); Pittsford, 14 June, 1902, *Eggleston 2783* (Phil. Acad. Nat. Sci. Herb.); on cold bog, Rutland, 21 June, 1899, *Eggleston 1383* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Mendon, 2 July, 1900, *Eggleston 2040* (Mo. Bot. Gard. Herb.); Windham, coll. of 1901, *W. H. Blanchard* (Gray Herb.).

New York: Stony Creek Ponds, Adirondack Mountains, 29 June, 1899, *Rowlee, Wiegand & Hastings* (Gray Herb.); north woods, Herkimer Co., coll. of 1864, *Paine* (Gray Herb.); meadow, South Branch, Herkimer Co., Aug., 1879, *Tweedy* (U. S. Nat. Herb.), form with somewhat less elongated leaves.

North Carolina: summit of Roan Mountain, Mitchell Co., alt. 1920 m., *Small & Heller 234* (Mo. Bot. Gard. Herb.).

55. S. pseudaureus Rydb. Bull. Torr. Bot. Club **24**:298. 1897; *ibid.* **27**: 180, *pl. 5, fig. 10.* 1900; Mem. N. Y. Bot. Gard. **1**:446. 1900; Fl. Colo. 397. 1906; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902; Piper, Contr. U. S. Nat. Herb. **11**:598. 1906; Nels. in Coulter & Nelson, Manual Cent. Rocky Mountains 582. 1909, in part; Daniels, Univ. Mo. Studies, Sci. Ser. **2**:252. 1911; Wooton & Standley, Contr. U. S. Nat. Herb. **19**:747. 1915.

An herbaceous perennial; stems erect, 3 to 7 dm. high, white-tomentulose in the axils of the leaves, along the margins of the petioles towards their base, and in the inflorescence, otherwise glabrous or nearly so; lower leaves long-petiolate, ovate-rotund to oblong-ovate, 1 to 10 cm. long, 1 to 6 cm. broad, rounded to acute at the apex, shallowly cordate, crenate to doubly serrate with somewhat incurved teeth; petioles 1 to 23 cm. long; stem-leaves petiolate or sessile, undivided or sublyrate to pinnatisect, and usually with rather sharply and doubly serrate-dentate and frequently revolute margins, more

or less attenuate; inflorescence a terminal few to many-headed corymbose cyme; heads 8 to 10 mm. high, radiate; involucre campanulate, calyculate; bracts of the involucre (13–) 21, linear, acute, 6 to 8 mm. long, glabrous except at the penicillate tip; ray-flowers 10 to 13, rays pale yellow; disk-flowers numerous; achenes glabrous.

Distribution: Saskatchewan, Alberta and British Columbia, south to New Mexico and California.

Specimens examined:

Saskatchewan: District of Assiniboia, 1 Aug., 1901, *Williamson* (C. S. Williamson Herb.).

Alberta: Laggan, Rocky Mountain Park, 13 July, 1904, *Macoun 65016* (Gray Herb. and Geol. Surv. Canada Herb.); trail to Burgess Pass, Yoho Valley, 28 Aug., 1904, *Macoun 65017* (Gray Herb. and Geol. Surv. Canada Herb.); Lake Louise, alt. 1830–2135 m., 17 July, 1906, *Brown 559* (Phil. Acad. Nat. Sci. Herb.); near Banff, 6 July, 1891, *Macoun* (U. S. Nat. Herb. 232000); Banff, alt. 1340 m., 7 July, 1907, *Butters & Holway 66* (U. S. Nat. Herb.); in swampy places, summit of South Kootenai Pass, 9 Aug., 1881, *Dawson 14768* (Geol. Surv. Canada Herb.); in wet places, North Kootenai Pass, 28 July, 1883, *Dawson 14815* (Geol. Surv. Canada Herb.).

British Columbia: Burgess Trail, vicinity of Field, alt. 1545–1830 m., 29 June and 16 July, 1906, *Brown 518* (Phil. Acad. Nat. Sci. Herb.); in woods, Emerald Lake, alt. 1310 m., 4 Aug., 1904, *Petersen 148* (Gray Herb., U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.); Bonaparte River, 18 June, 1889, *Macoun* (U. S. Nat. Herb. 219791), in part; Mount St. Thomas, between Kettle and Columbia Rivers, 8 Aug., 1902, *Macoun 64994* (Gray Herb. and Geol. Surv. Canada Herb.); grassy thickets, Guichon Creek, 8 July, 1888, *Dawson 14769* (Geol. Surv. Canada Herb.); damp places, between North Thompson and Bonaparte Rivers, alt. 1220 m., 18 June, 1889, *Macoun 14770* (Geol. Surv. Canada Herb.), in part; Trail, 9 June, 1902, *Macoun 64993* (Geol. Surv. Canada Herb.).

Montana: Midvale, 1 July, 1903, *Umbach 238* (U. S. Nat. Herb.); Big Fork, Flathead Co., 14 June, 1904, *Jones* (U. S. Nat. Herb.); Big Fork, 15 July, 1908, and Swan Lake, 25 Aug., 1908, *Clemens* (Field Mus. Herb. 376698 and 384938); MacDougal Peak, 31 July, 1908, *Clemens* (Mo. Bot. Gard. Herb.); Little Belt Pass, 10 Aug., 1896, *Flodman 918* (Mo. Bot. Gard. Herb.), CO-TYPE; Spanish Basin, Gallatin Co., alt. 1980 m., 28 June, 1897, *Rydberg & Bessey 5263* (Gray Herb., Berlin Herb., and N. Y. Bot. Gard. Herb.); Gallatin Basin, alt. 2130 m., 5 Aug., 1905, *Blankenship 291* (U. S. Nat. Herb., Mo. Bot. Gard. Herb., and Phil. Acad. Nat. Sci. Herb.).

Yellowstone National Park: Lone Star Geyser Basin, 7 Aug., 1897, *Rydberg & Bessey 5262* (U. S. Nat. Herb. and N. Y. Bot. Gard. Herb.); Gibbon Cañon, 28 Aug., 1899, *A. & E. Nelson 6748* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Yellowstone Falls, 5 Aug., 1885, *Letterman 77* (Mo. Bot. Gard. Herb.); without definite locality, 5 Aug., 1902, *Mearns 2860, 2978* (U. S. Nat. Herb.); Amethyst Creek, 14 Aug., 1887, *Knowlton* (U. S. Nat. Herb. 201412).

Colorado: open wet meadow, below Estes Park, 5 July, 1912, *Churchill* (J. R. Churchill Herb.); Wagon Wheel Gap, Mineral Co., July, 1882, *B. H. Smith* (Phil. Acad. Nat. Sci. Herb.); Mancos, 21 June, 1898, *Baker, Earle & Tracy 45* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.).

New Mexico: vicinity of Chama, Rio Arriba Co., alt. 715–870 m., 9 July, 1911, *Standley 6635* (U. S. Nat. Herb.); along the Pecos River, east of Glorieta, San Miguel Co., alt. 1980 m., *A. & E. Heller 3682* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.).

Idaho: West Fork of Priest River, alt. 900 m., 4 Aug., 1897, *Leiberg 2825* (U. S. Nat. Herb.); near Santianne Divide, west side, alt. 850 m., 23 June, 1895, *Leiberg 1020* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Granite Station, Kootenai Co., 30 July, 1892, *Sandberg, MacDougal & Heller 803* (U. S. Nat. Herb.); near Lewiston, 17 June, 1894, *Henderson* (U. S. Nat. Herb.); Fork of Wood River, alt. 1830 m., 25 July, 1895, *Henderson 3235* (U. S. Nat. Herb.); Twilight Gulch, Owyhee Co.,

alt. 1675 m., 23 June, 1911, *Macbride 973* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); House Creek, Owyhee Co., 29 June, 1912, *Nelson & Macbride 1808* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.).

Utah: Ogden, June, 1871, *Coulter* (U. S. Nat. Herb.).

Nevada: grassy lowlands, Bieroth's Ranch, McDonald Creek, 2 Aug., 1912, *Nelson & Macbride 2159* (U. S. Nat. Herb.); East Humboldt Mountains, alt. 1985 m., U. S. Geol. Exploration of the 40th Parallel, *Watson 667* (Gray Herb. and U. S. Nat. Herb.).

Washington: eastern Washington, 26 July, 1892, *Henderson* (Mo. Bot. Gard. Herb.); Ellensburg, 2 June, 1897, *Whited 442* (U. S. Nat. Herb.); along streams, Mount Paddo (Adams), 30 June, 1885, *Suksdorf* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Falcon Valley, July, 1885, *Suksdorf 571* (Gray Herb.); without definite locality, coll. of 1883, *Brandegee* (Gray Herb.), and coll. of 1889, *Vasey 537* (U. S. Nat. Herb.).

Oregon: Crow Creek, Wallowa Co., alt. 1295 m., 3 July, 1897, *Sheldon 8512* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); on Miller Trail, near Sled Springs, Imnaha National Forest, alt. 1265 m., 12 July, 1907, *Jardine 89* (U. S. Nat. Herb.); Union Co., coll. of 1879, *Cusick 755* (Gray Herb.); Minum River, 16 Aug., 1897, *Sheldon 8710* (U. S. Nat. Herb.); Big Meadows, Des Chutes River, Crook Co., alt. 1370 m., 23 July, 1894, *Leiberg 515* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Crater Lake, 10 Aug., 1897, *Austin 1610* (U. S. Nat. Herb.); Cascade Mountains, Oregon Boundary Commission, coll. of 1860, *Lyall* (Gray Herb.); Brown's Meadow on Rogue River, alt. 1300 m., 8 July, 1889, *Leiberg 4287* (U. S. Nat. Herb.); without definite locality, U. S. Exploring Expedition, *Wilkes 494* (U. S. Nat. Herb. 48748).

California: Goose Lake Valley, July, 1895, *Austin 558* (U. S. Nat. Herb. 666887); Davis Creek, Modoc Co., Aug., 1894, *Austin* (Phil. Acad. Nat. Sci. Herb.); Upper Funston Meadows, basin of the Upper Kern River, Tulare Co., alt. 1980 m., July, 1904, *Hall & Babcock 5569* (Gray Herb.).

Var. **flavulus** (Greene) Greenm. comb. nov.

S. flavulus Greene, Pittonia 4:108. 1900; Rydb. Bull. Torr. Bot. Club 27:185. 1900; Fl. Colo. 397. 1906, in part.

S. Balsamitae Nels. in Coulter & Nelson, Manual Cent. Rocky Mountains 583. 1909, in part, not Muhl.

Stems slender, 1.5 to 4 dm. high; leaves relatively small, the radical and lower stem-leaves ovate-rotund to ovate-oblong, .8 to 4 cm. long, 8 to 20 mm. broad, rounded to acute at the apex, crenate to serrate-dentate, more or less cordate at the base; petioles 1 to 8.5 cm. long; upper stem-leaves petiolate and sublyrate or sessile and laciniate to entire.

Distribution: southern Wyoming and Colorado.

Specimens examined:

Wyoming: river bottoms, Encampment, Carbon Co., alt. 2175 m., 15 June, 1901, *Tweedy 4132* (U. S. Nat. Herb.).

Colorado: Walden, Larimer Co., 8 July, 1903, *Goodding 1494* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Sapinero, alt. 2285 m., 19 June, 1901, *Baker 176* (Gray Herb., U. S. Nat. Herb., Greene Herb., and Mo. Bot. Gard. Herb.); Black Cañon, alt. 2135 m., 12 June, 1901, *Baker 114* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Veta Pass, 15 July, 1896, *Shear 3592* (U. S. Nat. Herb.); Arboles, Archuleta Co., 15 June, 1899, *Baker 707* (Greene Herb., Berlin Herb., and Mo. Bot. Gard. Herb.), TYPE.

56. **S. Burkei** Greenm. Ottawa Nat. 25:114. 1911; Ann. Mo. Bot. Gard. 2:626, *pl. 20, fig. 1*. 1915.

An herbaceous perennial, glabrous or nearly so; stems erect, 3 to 9 dm. high, simple or rarely branched, striate; lower leaves petiolate, ovate-oblong, 1 to 7 cm. long, 1 to 3.5 cm. broad, obtuse or rounded at the apex, crenate to serrate-dentate, cuneate to subtruncate at the base; petioles 2 to 12 cm. long; stem-leaves petiolate and sublyrate to sessile and pinnatisect; inflorescence a terminal few to many-headed corymbose cyme; heads 10 to 12 mm. high, radiate; involucre campanulate, calyculate; bracts of the involucre usually 21, linear-lanceolate, 6 to 8 mm. long, glabrous or floccose-tomentulose, more or less tinged with purple; ray-flowers about 12, rays yellow; disk-flowers numerous; achenes glabrous.

Distribution: Minnesota to British Columbia.

Specimens examined:

Minnesota: Itaska Lake, 25 June, 1891, *Sandberg 1036* (U. S. Nat. Herb.).

Montana: Glacier National Park, 9 July, 1914, *Hitchcock 11831* (U. S. Nat. Herb.); open ground, shore of Lake McDonald, alt. 950 m., 25 July, 1901, *Vreeland* (U. S. Nat. Herb. and Geol. Surv. Canada Herb.); Columbia Falls, 1 July, 1894, *Williams 68* (U. S. Nat. Herb.).

Idaho: wet soil, Kootenai Co., alt. 650 m., *Leiberg* (Mo. Bot. Gard. Herb.).

Rocky Mountains: Grand Saline, "R. M. E. side", *Burke* (Gray Herb.), TYPE; river margins, Silver City, 7 Aug., 1885, *Macoun* (Gray Herb. and Geol. Surv. Canada Herb. 14772); swamps, Kicking Horse Lake, alt. 1540 m., 10 Aug., 1890, *Macoun* (Geol. Surv. Canada Herb. 14810).

Alberta: bank of Bow River, vicinity of Banff, alt. 1370 m., 20 July, 1899, *McCalla 2045* (U. S. Nat. Herb.); by the reservoir, Banff, 30 Oct., 1899, *Sanson* (Geol. Surv. Canada Herb. 22288); in vicinity of Banff, July, 1906, *Sanson* (Geol. Surv. Canada Herb. and Field Mus. Herb.); Banff, 28 July, 1904, *Farr* (Field Mus. Herb.); northern slopes of Crows Nest Pass, 31 July, 1887, *Macoun* (Geol. Surv. Canada Herb. 22785), in part.

British Columbia; open thicket, Spence's Bridge, 31 May, 1889, *Macoun* (Geol. Surv. Canada Herb. 14811), in part; cleared land at Homer Lake, 19 June, 1905, *Shaw 722* (Phil. Acad. Nat. Sci. Herb. and Mo. Bot. Gard. Herb.); Sophie Mountain, between Kettle and Columbia Rivers, 17 July, 1902, *Macoun 64990, 64991* (Gray Herb. and Geol. Surv. Canada Herb.); Skagit Valley, alt. 760–925 m., 21 Aug., and 10 July, 1905, *Macoun 69358, 69359* (Gray Herb. and Geol. Surv. Canada Herb.); shaded banks, mouth of Silica Creek, Chilliwack River, 29 June, 1901, *Macoun 26685* (Geol. Surv. Canada Herb., Greene Herb., and Gray Herb.), in part; on a bog, Chilliwack Lake, 19 July, 1901, *Macoun 26682, 26682a* (Geol. Surv. Canada Herb.); in a marsh east of Chilliwack Lake, 25

July, 1901, *Macoun* (Geol. Surv. Canada Herb., Gray Herb., and Mo. Bot. Gard. Herb.); Middle Creek, Chilliwack River, 2 Aug., 1901, *Macoun 26681* (Geol. Surv. Canada Herb. and Greene Herb.); in thicket by stream at 150-mile house, Cariboo, 15 July, 1900, *Wilson 700* (Geol. Surv. Canada Herb.).

57. S. gaspensis Greenm.[1]

An herbaceous perennial, commonly lightly floccose-tomentulose in the axils of the leaves; stems one to several from a common base, erect, 2.5 to 5 dm. high; lower leaves petiolate, broadly ovate to elliptic-lanceolate, .5 to 8 cm. long, 1 to 3.5 cm. broad, thin, glabrous on both surfaces, or sometimes in the early stages sparingly hairy, especially on the under surface, glabrate, rounded to obtuse at the apex, crenate-dentate, abruptly narrowed at the base into a slender petiole 1 to 12 cm. in length; inflorescence a terminal several-headed corymbose cyme; involucre campanulate, calyculate, glabrous or slightly pubescent; bracts of the involucre 13 to 21, linear-lanceolate, 4 to 6 mm. long; ray-flowers 8 to 12, rays yellow; disk-flowers numerous; achenes glabrous.

Distribution: Newfoundland, eastern Quebec, and northern Maine.

Specimens examined:

Newfoundland: meadow and damp talus on hill north of Tilt Cove, Notre Dame Bay, 22 Aug., 1911, *Fernald & Wiegand 6405* (Gray Herb.).

Quebec: cold walls of Percé Mountain, Percé, Gaspé Co., 25 July, 1905, *Williams, Collins & Fernald* (Gray Herb.),

[1]**Senecio gaspensis** Greenm. sp. nov., herbaceus perennis ad basin et in axillis foliorum plerumque albo-flocculoso-tomentulosus; caulibus erectis 2.5–5 dm. altis; foliis inferioribus petiolatis late ovatis vel elliptico-lanceolatis .5–8 cm. longis 1 to 3.5 cm. latis membranaceis utrinque glabris vel juventa subtus sparse pubescentibus denique glabratis, ad apicem rotundatis vel obtusis, crenato-dentatis, ad basin abrupte contractis; petiolis gracilibus 1–12 cm. longis; inflorescentiis corymboso-cymosis terminalibus; capitulis 7–10 mm. altis, radiatis; involucris campanulatis glabris vel parce pubescentibus; bracteis involucri 13–21 lineari-lanceolatis 4–6 mm. longis; floribus femineis 8–12 ligulatis, ligulis flavibus; floribus disci numerosis longioribus quam squamae involucri; achaeniis glabris.—On cold walls of Percé Mountain, Percé, Gaspé Co., Quebec, 25 July, 1905, *Williams, Collins & Fernald* (Gray Herb.), TYPE; Grand Coupe, Percé, and Bonaventure Island, Gaspé Co., Aug., 1907, *Fernald & Collins 1204, 1205* (Gray Herb.); between the Forks and Brûlé Brook, Little Cascapedia River, Bonaventure Co., 29, 30 July, 1904, *Collins, Fernald & Pease* (Gray Herb. and U. S. Nat. Herb.); shaded alluvium, Fort Kent, Maine, 6 July, 1904, *Fernald* (Gray Herb.).

TYPE; cold northerly calcareous walls of the Grand Coupe, Percé, Gaspé Co., 6 Aug., 1907, *Fernald & Collins 1204* (Gray Herb.); limestone cliffs, Bonaventure Island, Gaspé Co., 7 Aug., 1907, *Fernald & Collins 1205* (Gray Herb.); alluvial thickets, between the Forks and Brûlé Brook, Little Cascapedia, *Collins, Fernald & Pease* (Gray Herb. and U. S. Nat. Herb.).

Maine: shaded alluvium, Fort Kent, 6 July, 1904, *Fernald* (Gray Herb.); rocky river flat, Fort Kent, 10 July, 1908, *Mackenzie 3418* (U. S. Nat. Herb. 648722).

58. S. Crawfordii Britt. Torreya **1**:21. 1901; Manual 1027. 1901, and ed. 2, 1905; Britton & Brown, Ill. Fl. **3**:545, *fig. 4628*. 1913.

S. Balsamitae var. *Crawfordii* (Britt.) Greenm. in Rhodora **10**:69. 1908, and in Gray, Manual, ed. 7, 854. 1908.

An herbaceous perennial, glabrous throughout or slightly tomentose on the base of the petioles and in the leaf-axils; stems erect, 3 to 6 dm. high; lower leaves long-petiolate, ovate to elliptic-lanceolate, the blades 1 to 8 cm. long, 1 to 3.5 cm. broad, rounded or obtuse at the apex, crenate to serrate-dentate, usually abruptly narrowed at the base, glabrous on both surfaces; petioles slender, 2 to 18 cm. long; stem-leaves petiolate and more or less lyrate to sessile and incised-serrate; inflorescence a few-headed corymbose cyme; heads about 1 cm. high, radiate; involucre campanulate, calyculate; bracts of the involucre 13 to 21, narrowly lanceolate, 6 to 8 mm. long, acute, glabrous, often purplish-tipped; ray-flowers 8 to 12, rays yellow, conspicuous; disk-flowers numerous; achenes glabrous.

Distribution: western New Jersey and southeastern Pennsylvania.

Specimens examined:

New Jersey: Assinipink Creek, near Trenton and New Brunswick trolley bridge, 28 May, 1904, *Brown* (Phil. Acad. Nat. Sci. Herb.); Abbott's meadow, below Trenton, 29 May, 1904, *Brown* (Phil. Acad. Nat. Sci. Herb.); Crosswick's Creek, 29 May, 1904, *Williamson* (C. S. Williamson Herb.); wet meadow between Springdale and Orchard, Camden Co., 20 May, 1905, *Stone* (Phil. Acad. Nat. Sci. Herb.).

Pennsylvania: in low wet ground, Tullytown, Bucks Co., 12 May, 1894, *MacElwee* (Phil. Acad. Nat. Sci. Herb.); swamp, near Tullytown, 20 May, 1899, *Fretz* (Phil. Acad. Nat. Sci. Herb.); Tullytown, 30 May, 1899, and 22 May, 1900, *Crawford* (Phil. Acad. Nat. Sci. Herb.); Tullytown, May, 1902, *Crawford & Brown* (Phil. Acad. Nat. Sci. Herb.); wet places in bog near Willow Grove, Montgomery Co., 25 May, 1899, *MacElwee 326* (Phil. Acad. Nat. Sci. Herb.); Fraser's bog, east of Willow Grove, 29 May, 1906, *Williamson* (Phil. Acad. Nat. Sci. Herb.); Fraser's bog, one mile southeast of Willow Grove, 17 and 23 June, 1902, *Van Pelt* (Phil. Acad. Nat. Sci. Herb.), form; Fraser's bog, near Bayer's Corner, 12 May, 1910, *Long 3307* (Phil. Acad. Nat. Sci. Herb.); near Philadelphia, 29 May, 1901, *Crawford* (Gray Herb.).

59. **S. quaerens** Greene, Leafl. Bot. Obs. & Crit. 1:214. 1906; Wooton & Standley, Contr. U. S. Nat. Herb. 19:747. 1915.

S. prionophyllus Greene, Leafl. Bot. Obs. & Crit. 1:212. 1906, not *S. prionophyllus* Greene, Ottawa Nat. 15:259. 1902.

An herbaceous perennial, glabrous or slightly white-floccose-tomentulose, especially towards the base of the stem, on the petioles, and in the leaf-axils; stems erect, 3 to 6 dm. high, rather leafy at the base, nearly naked above; lower leaves petiolate, subobovate to ovate-oblong, 1 to 8 cm. long, 1 to 3 cm. broad, rounded to obtuse at the apex, crenate to subserrate-dentate; petioles 1.5 to 14 cm. long; stem leaves petiolate and sublyrate to sessile and more or less pinnatisect; inflorescence a one to many-headed corymbose cyme; heads about 1 cm. high, radiate; involucre campanulate, sparingly calyculate, slightly tomentulose at the base; bracts of the involucre linear-lanceolate, 5 to 7 mm. long, acute; ray-flowers 8 to 12, rays yellow; disk-flowers numerous; achenes glabrous.

Distribution: mountains of New Mexico.

Specimens examined:

New Mexico: moist places on the west fork of the Gila River, Mogollon Mountains, Socorro Co., alt. about 2285 m., 7 Aug., 1903, *Metcalfe 409* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.), TYPE; Willow Creek, Mogollon Mountains,

Socorro Co., 8 Aug., 1900, *Wooton* (U. S. Nat. Herb.); Santa Magdalena Mountains, June, 1881, *Vasey* (U. S. Nat. Herb.).

60. S. platylobus Rydb. Bull. Torr. Bot. Club **27**:181, *pl. 6, fig. 8.* 1900.

An herbaceous perennial, glabrous or essentially so; stems erect, 2.5 to 4 dm. high, striate; lower leaves petiolate, obovate or broadly oval, including the petiole 3.5 to 14 cm. long, 1 to 3 cm. broad, irregularly dentate; stem-leaves petiolate and sublyrate to sessile and pinnately divided into oblong to cuneate, rather conspicuous, rounded or acute lateral divisions; inflorescence a many-headed corymbose cyme; heads 8 to 10 mm. high, radiate; involucre campanulate, sparingly calyculate; bracts of the involucre 13 to 21, lanceolate, acute, 5 to 6 mm. long, glabrous, somewhat stramineous; ray-flowers 10 to 12, rays yellow; disk-flowers numerous; achenes glabrous.

Distribution: mountains of Utah.

Specimens examined:

Utah: Wasatch Mountains, coll. of 1869, *Watson 671* (Torrey Herb.), TYPE; cañon bottoms, Provo, Wasatch Mountains, 16 June, 1902, *Goodding 1115* (Mo. Bot. Gard. Herb.); Red Rock Cañon, near Salt Lake City, 11 June, 1905, *Rydberg 6064* (U. S. Nat. Herb.); rich woods in mountain cañon, *Armstrong 336* (Margaret Armstrong Herb.); Mendon, 17 June, 1898, *Mulford 124* (Mo. Bot. Gard. Herb.).

There appears to have been some confusion of the material which was distributed by Dr. Watson under his number 671. The specimen in the United States National Herbarium agrees very well, particularly in habit and foliar characters, with typical forms of *S. crocatus*, but it differs markedly from Watson's 671 in the Gray Herbarium (which is apparently *S. rubricaulis* Greene) and likewise from the specimen bearing the same number in the Torrey Herbarium, namely the type of *S. platylobus* Rydb.

61. S. crocatus Rydb. Bull. Torr. Bot. Club **24**:299. 1897; *ibid.* **27**:177. 1900, in part; Mem. N. Y. Bot. Gard. **1**:446. 1900, at least as to synonymy; Fl. Colo. 396. 1906, in part; Greene,

Pittonia 4:114. 1900; Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains 582. 1909, in part; Daniels, Univ. Mo. Studies, Sci. Ser. 2:252. 1911, in part.

S. aureus L.? var. *croceus* Gray, Proc. Acad. Nat. Sci. Phil. 15:68. 1863, i. e., Hall and Harbour No. 332, in part, and Parry No. 405, not *S. croceus* DC.

S. aureus var. *croceus* Gray, Syn. Fl. N. Am. 1²:391. 1884, and ed. 2, 1886, in part.

S. longipetiolatus Rydb. Bull. Torr. Bot. Club 27: 176. 1900; Fl. Colo. 396. 1906; Coulter & Nelson, Manual Cent. Rocky Mountains 582. 1909.

S. Tracyi Rydb. Bull. Torr. Bot. Club 33:159. 1906; Fl. Colo. 397. 1906.

S. pyrrhochrous Greene, Pl. Baker. 3:24. 1901.

An herbaceous perennial, glabrous throughout or slightly tomentulose in the axils of the bracts of the inflorescence; stems erect, 1 to 7.5 dm. high from a rather stout rootstock, striate; lower leaves petiolate, oblong-ovate, subcordate to abruptly contracted at the base, rounded, obtuse or submucronate at the apex, entire to somewhat crenate-dentate; petioles 1 to 12 cm. long; stem-leaves petiolate and sublyrate to sessile and semiamplexicaul; inflorescence a few to many-headed corymbose cyme; heads in anthesis 8 to 10 mm. high, radiate; involucre campanulate, sparingly calyculate; bracts of the involucre (13–) 21, linear-lanceolate, 5.5 to 8 mm. long, acute, glabrous, more or less tinged with purple; ray-flowers 10 to 12, rays orange-red or saffron-colored varying to yellow; disk-flowers numerous; achenes glabrous.

Distribution: mountains of Colorado and Utah.

Specimens examined:

Colorado: Medicine Bow Mountains, 3 Aug., 1891, *Crandall* (U. S. Nat. Herb.); Rocky Mountain Flora, Lat. 39–41°, coll. of 1862, *Hall & Harbour 332* (Gray Herb.), in part, TYPE; Middle Park, coll. of 1862, *Parry 405* (Gray Herb., Mo. Bot. Gard. Herb., and U. S. Nat. Herb. 349244); without definite locality, *Wolf & Rothrock 581* (Gray Herb., U. S. Nat. Herb., and Phil. Acad. Nat. Sci. Herb.); Gray's Peak, July, 1888,

Eastwood (U. S. Nat. Herb.); Park Co., *Williamson* (C. S. Williamson Herb.); Dickey, below Breckenridge, 2 Sept., 1885, *ex Herb. Fritchey* (Mo. Bot. Gard. Herb.); near Breckenridge, coll. of 1892, *Wislizenus 1086*, and Aug., 1901, *Mackenzie 211* (Mo. Bot. Gard. Herb.); Mt. Baldy, 15 July, 1906, *Anderson* (Mo. Bot. Gard. Herb.); vicinity of Twin Lakes, 2 Aug., 1873, *Coulter* (Phil. Acad. Nat. Sci. Herb.); Mt. Lincoln, alt. 3650 m., 9 July, 1873, *Coulter* (U. S. Nat. Herb.); Weston's Pass, 18 July, 1873, *Coulter* (U. S. Nat. Herb.); damp meadows, Elk Mountains, coll. of 1881, *Brandegee* (Mo. Bot. Gard. Herb.); Jack's Cabin, Gunnison Co., alt. 2520 m., 26 Aug., 1901, *Baker 612* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); vicinity of Mount Carbon, Gunnison Co., alt. 2750 m., 6 July, 1910, *Eggleston 5866* (U. S. Nat. Herb.); Marshall Pass, 27 July, 1896, *Shear 5162* (U. S. Nat. Herb.); Sargents, Saguache Co., alt. 2580 m., 5 July, 1901, *Baker 348* (Gray Herb., U. S. Nat. Herb., Greene Herb., and Mo. Bot. Gard. Herb.); Silverton, 5 Aug., 1897, *Shear 4900* (U. S. Nat. Herb.); Hamor's Lake, north of Durango, alt. 2740 m., 24 July, 1898, *Baker, Earle & Tracy 625* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.).

Utah: Wasatch Mountains, alt. 1525 m., May, 1869, *Watson 671* (U. S. Nat. Herb.); Fish Lake, National Forest, alt. 2925 m., 19 July, 1913, *Arriveé* (U. S. Nat. Herb.).

Var. **Wolfii** Greenm. comb. nov.

S. Wolfii Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902.

Stems slender, 2 to 3 dm. high; lower leaves ovate-rotund to ovate-oblong, 7 to 20 mm. long, 5 to 13 mm. broad, rounded or obtuse at the apex, entire, subcordate to cuneate at the base. Similar to the species but somewhat more slender and with smaller leaves.

Distribution: mountains of Colorado.

Specimens examined:

Colorado: South Park, Lieut. Wheeler's Expedition, 1873, *Wolf & Rothrock 582, 586* (Gray Herb. and U. S. Nat. Herb.), TYPE; meadows, South Cottonwood Gulch, Chaffee Co., alt. 3050 m., 9 July, 1892, *Sheldon 481* (U. S. Nat. Herb.).

62. S. aquariensis Greenm.[1]

An herbaceous perennial, glabrous or slightly tomentulose in the inflorescence; stems erect, solitary or closely cespitose, 2 to 3.5 dm. high; lower leaves petiolate, ovate to oblong-lanceolate, 1 to 7 cm. long, .5 to 2 cm. broad, obtuse to acute, entire, glabrous on both surfaces; petioles 1 to 6 cm. long; stem-leaves petiolate and sublyrate to sessile, semiamplexicaul and more or less pinnatisect; inflorescence a terminal rather close corymbose cyme; heads numerous, 8 to 10 mm. high, sparingly calyculate, radiate; involucre campanulate; bracts of the involucre 13 (–21), lanceolate, 5 to 6 mm. long, acute, glabrous; ray-flowers 10 to 12, rays yellow; disk-flowers numerous; achenes glabrous.

Distribution: high plateaus of Utah.

Specimens examined:

Utah: Aquarius Plateau, alt. 3050 m., 5 Aug., 1875, *Ward 505* (Mo. Bot. Gard. Herb., Gray Herb., U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Field Mus. Herb.), TYPE; Bear River Valley, coll. of 1877, *Palmer 267½* (Gray Herb., U. S. Nat. Herb. 782529 in part, and Mo. Bot. Gard Herb.).

63. S. dimorphophyllus Greene, Pittonia **4**:109. 1900; Rydb. Bull. Torr. Bot. Club **27**:178. 1900; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902.

S. heterodoxus Greene ex Rydb. Bull. Torr. Bot. Club **27**:178. 1900; Fl. Colo. 396. 1906, in synonymy.

S. aureus var. *croceus* Gray, Proc. Acad. Nat. Sci. Phil. **15**:68. 1863, i. e., Hall & Harbour No. 332, in part; Gray, Syn. Fl. N. Am. **1**[2]:391. 1884, and ed. 2, 1886, in part; Porter &

---

[1]**Senecio aquariensis** Greenm. sp. nov., herbaceus perennis glabrus vel in inflorescentiis leviter tomentosus; caulibus erectis 2–3 dm. altis solitariis vel dense caespitosis; foliis inferioribus petiolatis ovatis vel oblongo-lanceolatis 1–7 cm. longis .5–2 cm. latis obtusis vel acutis integris vel paulo dentatis utrinque glabris ad basin abrupte cuneatis vel raro subcordatis; petiolis 1–6 cm. longis; foliis superioribus petiolatis et sublyratis vel sessilibus plus minusve pinnatisectis semiamplexicaulibusque; inflorescentiis terminalibus conferte corymboso-cymosis; capitulis numerosis 8–10 mm. altis parce calyculatis radiatis; involucris campanulatis; bracteis involucri 13 (–21) lanceolatis 5–6 mm. longis acutis glabris; floribus femineis 10–12, ligulis flavibus; floribus disci numerosis; achaeniis glabris.—Collected on the Aquarius Plateau, alt. 3050 m., 5 Aug., 1875, *Ward 505* (Mo. Bot. Gard. Herb., Gray Herb., U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Field Mus. Herb.); Bear River Valley, coll. of 1877, *Palmer 267½* (Gray Herb., U. S. Nat. Herb. 782529 in part, and Mo. Bot. Gard. Herb.).

Coulter, Syn. Fl. Colo. 82. 1874, in part; Coulter, Manual Rocky Mountain Region 211. 1885, in part.

S. crocatus Rydb. Mem. N. Y. Bot. Gard. **1**:446. 1900, in part; Bull. Torr. Bot. Club **27**:177, *pl. 5, fig. 13*. 1900, as to description, illustration, and most of specimens cited, not as to synonymy; Fl. Colo. 396. 1906, mainly; Daniels, Fl. Boulder 252. 1911, mainly; Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains 582. 1909, in part.

An herbaceous perennial, glabrous or essentially so throughout; stems one to several from a common base, erect or ascending, 1 to 3 dm. high; lower leaves ovate, subobovate, broadly spatulate or somewhat oblong-lanceolate, 1 to 4 cm. long, .5 to 2.5 cm. broad, rounded to obtuse at the apex, entire to crenate, narrowed at the base into a winged petiole equalling or exceeding the blade; stem-leaves mostly sessile, oblong-lanceolate to triangular-ovate, frequently conspicuously dilated at the base and amplexicaul; inflorescence a few to several-headed terminal corymbose cyme; heads about 1 cm. high, radiate; involucre campanulate, calyculate; bracts of the involucre about 21, linear-lanceolate, 6 to 7 mm. long, acuminate, acute, glabrous or slightly tomentulose, frequently reddish-tipped; ray-flowers 10 to 12, rays yellow; disk-flowers numerous; achenes glabrous.

Distribution: mountains of Wyoming and Colorado.

Specimens examined:

Wyoming: La Plata Mines, 21 Aug., 1895, *A. Nelson 1769* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); wet, subalpine woods, Nash's Fork, Albany Co., 15 Aug., 1908, *A. Nelson 9148* (Mo. Bot. Gard. Herb.); grassy ground, below snow, Bridges Peak, Carbon Co., 24 Aug., 1903, *Goodding 1980* (U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.).

Colorado: alpine meadows, summit of North Park Range, Larimer Co., 10 Aug., 1903, *Goodding 1820* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); about timberline, above Berthoud's Pass, 14 Sept., 1874, *G. Engelmann* (Mo. Bot. Gard. Herb.); timberline, Long's Peak, 5 Aug., 1886, *Letterman*

(Mo. Bot. Gard. Herb.); foot of Kelso Mountain, near Torrey's Peak, 14 Aug., 1885, *Letterman* (Mo. Bot. Gard. Herb.); Front Range, alt. 3500 m., 6 July, 1896, *Crandall* (Mo. Bot. Gard. Herb.); Grays Peak, above timberline, 31 Aug., 1884, *B. H. Smith* (Phil. Acad. Nat. Sci. Herb.); Grays Peak, alt. 3650–3800 m., 15 Aug., 1885, *Letterman* (Mo. Bot. Gard. Herb. and Field Mus. Herb.); Powell's Colorado Expl. Exp., 1868, Lat. 40–41°, *Vasey 340B* (Gray Herb. and Mo. Bot. Gard. Herb.); Lat. 39–41°, coll. of 1862, *Hall & Harbour 332* (U. S. Nat. Herb. 48721, Phil. Acad. Nat. Sci. Herb., and Field Mus. Herb. 314668); Lat. 39–41°, coll. of 1862, *Hall & Harbour 331* (U. S. Nat. Herb. 48766), in part, and *Hall & Harbour 115* (Gray Herb.), in part; without definite locality, coll. of 1871, *Brandegee 132* (Mo. Bot. Gard. Herb.); Breckenridge, coll. of 1892, *Wislizenus 1067* (Mo. Bot. Gard. Herb.); Mt. Parry, coll. of 1872, *Gray* (Gray Herb.); Golden City, 12 July, 1871, *Greene 528* (Gray Herb.); Golden, 13 July, 1885, *Letterman* (Mo. Bot. Gard. Herb.); Peak Valley, 21 Aug., 1901, *F. E. & E. S. Clements 485* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Cameron Pass, alt. 3500 m., 14 July, 1896, *Baker* (Mo. Bot. Gard. Herb.); meadows, South Cottonwood Gulch, Chaffee Co., alt. 3050 m., 9 July, 1892, *Sheldon 100* (U. S. Nat. Herb.); Gunnison Co., July, 1889, *Eastwood* (U. S. Nat. Herb.); Mineral Point, July, 1887, *Hempton* (Mo. Bot. Gard. Herb.); near Pagosa Peak, Mineral Co., alt. 3200 m., 6 Aug., 1899, *Baker 705* (Gray Herb., Berlin Herb., Greene Herb., and Mo. Bot. Gard. Herb.), TYPE; head of Vallecito, alt. 3000–3800 m., 2 Sept., 1903, *Knowlton 3* (U. S. Nat. Herb.); La Plata Mountains, alt. 3650 m., 15 July, 1896, *Tweedy 537* (U. S. Nat. Herb.); Little Kate Mine, La Plata Mountains, alt. 3500 m., 14 July, 1898, *Baker, Earle & Tracy 569* (Gray Herb., U. S. Nat. Herb., Greene Herb., and Mo. Bot. Gard. Herb.), TYPE of *S. heterodoxus* Greene; Farnham, 10 July, 1891, *E. C. Smith* (Mo. Bot. Gard. Herb.).

64. **S. Farriae** Greenm. Bot. Gaz. **42**:147. 1906; Contr. Bot. Lab. Univ. Penn. **3**:74. 1907; Ottawa Nat. **25**:115. 1911.

An herbaceous perennial, glabrous except for a persistent white tomentum in the axils of the leaves; stems erect or as-

cending, 1 to 3 dm. high, simple or branched from near the base; lower leaves ovate to slightly obovate, the blade 1 to 4 cm. long, 1 to 2.5 cm. broad, rounded at the apex, crenate to subentire, contracted at the base into a narrowly winged petiole equalling or exceeding the blade; stem-leaves petiolate and sublyrate to sessile and somewhat irregularly pinnatifid, the uppermost leaves reduced to mere bracts; heads about 1 cm. high, radiate; involucre campanulate, slightly calyculate, sparingly tomentulose at the base; bracts of the involucre about 21, linear-lanceolate, 7 to 8 mm. long, frequently reddish-tipped; ray-flowers 10 to 14, rays yellow; disk-flowers numerous, 50 to 60; achenes glabrous.

Distribution: mountains of Alberta to Washington.

Specimens examined:

Alberta: near Banff, alt. 1500 m., 8 June, 1904, *Farr* (Univ. Penn. Herb. and Field Mus. Herb.), TYPE; vicinity of Banff, July, 1906, *Sanson 81260* (Geol. Surv. Canada Herb. and Mo. Bot. Gard. Herb.); vicinity of Basin, near Banff, alt. 1400 m., 8 and 18 June, 1906, *Brown 20* (Phil. Acad. Nat. Sci. Herb.); in deep moss in stream-bed below warm sulphur spring, vicinity of Banff, alt. 1370 m., 15 June, 1899, *McCalla 2049* (U. S. Nat. Herb.); Sulphur Springs, Banff, alt. 1415 m., 11 June, 1906, *Butters & Rosendahl 1324* (Field Mus. Herb.); Crows Nest Lake, alt. 1385 m., 9 July, 1883, *Dawson* (Geol. Surv. Canada Herb. 14800), in part; Devil's Head Lake, alt. 1385 m., 13 July, 1899, *Sanson* (Geol. Surv. Canada Herb. 22125); crossing of McLeod's River, 19 June, 1898, *Spreadborough* (Geol. Surv. Canada Herb. 19725); in grass along Bragg's Creek, Elbow River, 26 June, 1897, *Macoun* (Geol. Surv. Canada Herb. 22784); damp places, Red Deer, coll. of 1895, *Gaetz* (Geol. Surv. Canada Herb. 11622).

Washington: on rocky bar of Columbia River at Wenatchee, 25 May, 1899, *Whited 1096* (U. S. Nat. Herb.).

65. S. Hartianus Heller, Bull. Torr. Bot. Club **26**:622. 1899.

S. flavulus Wooton & Standley, Contr. U. S. Nat. Herb. **19**:747. 1915, in part, not Greene.

An herbaceous perennial, at first somewhat white-tomentulose, later more or less glabrate; stems erect, 2 to 5 dm. high,

lower leaves petiolate, ovate-rotund, ovate-oblong to subobovate, 1 to 3.5 cm. long, .5 to 2 cm. broad, rounded to obtuse at the apex, minutely crenate to serrulate, subcordate to abruptly contracted to a cuneate base; petioles 1 to 6.5 cm. long; inflorescence a few to many-headed corymbose cyme; heads 6 to 10 mm. high, radiate; involucre campanulate, sparingly calyculate, tomentulose; bracts of the involucre 13 to 21, linear, 4 to 6 mm. long; ray-flowers about 12, rays pale yellow; disk-flowers numerous; achenes glabrous.

Distribution: mountains of New Mexico and Arizona.

Specimens examined:

New Mexico: Winsor's Ranch, Pecos River National Forest, alt. 2500 m., 30 June, and 3 July, 1908, *Standley 4058, 4061, 4165* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); marsh, Kingston, Sierra Co., alt. 2000 m., 25 May, 1904, *Metcalfe 931* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.).

Arizona: vicinity of Flagstaff, alt. 2135 m., 5 July, 1898, *MacDougal 230* (Gray Herb. and Phil. Acad. Nat. Sci. Herb.), TYPE; San Francisco Mountains, 7 July, 1892, *Toumey 663* (Gray Herb. and U. S. Nat. Herb.); San Francisco Mountains, 21 Aug., 1889, *Knowlton 64* (U. S. Nat. Herb.); Mt. Agassiz, coll. of 1884, *Lemmon 3283* (Gray Herb.); near Kendrick Mountains, alt. 2000 m., 7 July, 1901, *Leiberg 5663* (U. S. Nat. Herb.); Cooley's Ranch, Navajo Co., 1 July, 1912, *Goodding 1108* (U. S. Nat. Herb.).

66. **S. plattensis** Nutt. Trans. Am. Phil. Soc. N. S. **7**:413. 1841; Britton & Brown, Ill. Fl. **3**:478, *fig. 4039*. 1898, and ed. 2, 543, *fig. 4623*. 1913; Heller, Cat. N. Am. Pl. 146. 1898, and ed. 2, 230. 1900; Rydb. Mem. N. Y. Bot. Gard. **1**:445. 1900, and Bull. Torr. Bot. Club **27**:185, *pl. 6, fig. 14*. 1900; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902; Britton, Manual 1026. 1901, and ed. 2, 1905; Rydb. Fl. Colo. 396. 1906; Coulter & Nelson, Manual Cent. Rocky Mountains 581. 1909; Daniels, Univ. Mo. Studies, Sci. Ser. **2**:251. 1911.

S. balsamitae Torr. in Nicollet's Report, App. B, 153 [237]. 1843, not Muhl.

S. aureus var. *Balsamitae* Torr. & Gray, Fl. N. Am. **2**:442. 1843, in part; Gray in Boston Jour. Nat. Hist. **6**:231. 1857; Gray, Syn. Fl. N. Am. **1**[2]:391. 1884, and ed. 2, 1886, in part.

S. camporum Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902.

S. pseudotomentosus Mack. & Bush, Trans. Acad. Sci. St. Louis **12**:88, *pl. 17*. 1902.

An herbaceous perennial, usually more or less persistently white-floccose-tomentulose, rarely glabrous throughout; stems erect, one to several from a common base, 1 to 4 dm. high; leaves variable, the lower ovate-oblong to lanceolate or somewhat oblanceolate, 1 to 8 cm. long, .5 to 4 cm. broad, rounded to obtuse at the apex, crenate to serrate-dentate, subcordate to gradually narrowed at the base; petioles 1 to 15 cm. long; stem-leaves petiolate and sublyrate to sessile and very irregularly pinnatisect; inflorescence a terminal corymbose cyme; heads usually numerous, 8 to 10 mm. high, radiate; involucre campanulate, calyculate; bracts of the involucre 13 (–21), linear-lanceolate, 5 to 6 mm. long, glabrous or slightly tomentulose, penicillate; ray-flowers 10 to 12, rays yellow; disk-flowers numerous; achenes usually hispidulous along the angles, sometimes glabrous.

Distribution: southwestern Ontario to Saskatchewan and eastern Montana, south to Louisiana and Texas.

Specimens examined:

Ontario: on sand dunes, Port Franks, Lambton Co., 24 May, 1906, and 9 Aug., 1907, *Dodge 298, 108* (U. S. Nat. Herb.); Camlachie, 18 June, 1901, *Macoun* (Gray Herb. and U. S. Nat. Herb.); northeast of Sarnia, 5 June, 1897, *Dodge 297* (U. S. Nat. Herb.).

Manitoba: Stony Mountain, 14 June, 1887, *Fowler* (Mo. Bot. Gard. Herb.); open places south of Sewell, 12 June, 1876, *Macoun 12232* (Geol. Surv. Canada Herb.); gravelly or rocky places, Fort Ellice, 20 June, 1879, *Macoun 14799* (Geol. Surv. Canada Herb.).

Saskatchewan: Long Lake (Last Mountain Lake), 6 July, 1879, *Macoun 48* (Gray Herb.).

Michigan: dry fields and dryish woods, near Rochester, 2 June, 1912, and 25 May, 1913, *Farwell 2616, 3383, 3394* (Mo. Bot. Gard. Herb.); sterile hills, and in marl beds, Parkdale Farm, 2 June, 1912, 25 May, and 8 June, 1913, and 30 May, 1914, *Farwell 2608, 3414, 3443, 3655* (Mo. Bot. Gard. Herb.); dry soil in oak openings, Grand Rapids, 12 June, 1893, *Cole* (Gray Herb.); without definite locality, coll. of 1902, *H. L. Clark* (U. S. Nat. Herb. 413298).

Indiana: Notre Dame, 2 June, 1908, *Nieuwland*, and 14 May, 1913, *Nieuwland 11079* (Mo. Bot. Gard. Herb.).

Wisconsin: Fort Howard, on beaver dam, 15 June, 1878, *Schuette* (U. S. Nat. Herb. and Field Mus. Herb.).

Illinois: gravelly bluffs, Ringwood, coll. of 1860, *Vasey* (Gray Herb.); moist prairie, near Wady Petra, 20 May, 1896, *Chase* (Mo. Bot. Gard. Herb.); dry gravelly soil, Peoria, May and June, 1904, *McDonald* (Gray Herb.); vicinity of Oquawka, *Patterson* (Gray Herb. and Field Mus. Herb.); Mississippi River valley opposite St. Louis, 13 May, 1874, *Eggert* (Gray Herb., U. S. Nat. Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.); dry hills, French Village, 14 May, 1875, 14 May, 1878, and 8 May, 1892, *Eggert* (Mo. Bot. Gard. Herb.); French Village, 23 April, 1878, *Eggert* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); French Village, 17 May, 1894, *Glatfelter* (Mo. Bot. Gard. Herb.); bluffs, near Belleville, April, 1834, (?) *Engelmann 592* (Mo. Bot. Gard. Herb.); without definite locality, *Brendel* (Berlin Herb. and Gray Herb.).

Missouri: Windsor Springs, 26 April, 1890, *Hitchcock* (Mo. Bot. Gard. Herb.); Cliff Cave, 3 May, 1901, *J. H. Kellogg* (Mo. Bot. Gard. Herb.); Kimmswick, 10 May, 1885, *Wislizenus 226* (Mo. Bot. Gard. Herb.), in part; Kimmswick, 9 May, 1915, *Drushel 1262* (Mo. Bot. Gard. Herb. and J. A. Drushel Herb.); sandy rocks, near Crystal City, 20 May, 1887, *Eggert* (Mo. Bot. Gard. Herb.); Potosi, 3 June, 1892, *Dewart 96* (Mo. Bot. Gard. Herb.); dry ground, near Bismarck, 30 April, 1893, *Eggert* (Mo. Bot. Gard. Herb.); Monteer, 24 May, 1900, 13 May, 1901, 2 May, 1902, and 27 April, 1907, *Bush 711, 455, 1487* and *1338* (Mo. Bot. Gard. Herb.); Grandin, 5 May, 1901, *Bush 344* (Mo. Bot. Gard. Herb.); Grandin, 6 May, 1905,

Bush 2706, 2706A (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Butler Co., 1 May, 1905, *Bush 2558* (Mo. Bot. Gard. Herb.); Pleasant Grove, 20 May, 1900, *Bush 336* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Pleasant Grove, 21 May, 1900, *Bush 363* (Mo. Bot. Gard. Herb.); Jerome, 28 April, 1914, *J. H. Kellogg 453* (Mo. Bot. Gard. Herb.); Springfield, 28 April, 1888, *Weller 683* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Watson, 1 June, 1894, *Bush 180* (Gray Herb. and Mo. Bot. Gard. Herb.); prairies, Lee's Summit, 9 May, 1897, *Bush 349* (Mo. Bot. Gard. Herb.); in woods, Courtney, 24 May, 1903, *Bush 1830* (Mo. Bot. Gard. Herb.); wooded hills, Courtney, 12 May, 1913, *Bush 6995* (Mo. Bot. Gard. Herb.); rocky woods, Dodson, 5 May, 1914, *Bush 7105* (Mo. Bot. Gard. Herb.); sandy hills and low prairies, Cass Co., May–June, 1885, and April, 1871, *Broadhead* (Mo. Bot. Gard. Herb.); prairies, Webb City, 4 May, 1902, *E. J. Palmer 314* (Mo. Bot. Gard. Herb.); high prairies, Carthage, 14 May, 1911, and 4 May, 1913, *E. J. Palmer 3373, 3383, 3942* (Mo. Bot. Gard. Herb.); high sandy prairies, Alba, 7 May, 1914, *E. J. Palmer 5518* (Mo. Bot. Gard. Herb.); Eagle Rock, 14 June, 1897, *Bush 182* (Mo. Bot. Gard. Herb.); McDonald Co., 22 April, 1891, *Bush* (Mo. Bot. Gard. Herb.).

Arkansas: Corning, May, 1884, *Letterman* (Berlin Herb., fragment in Gray Herb.); "Monark," 2 May, 1905, *Bush 2592* (Mo. Bot. Gard. Herb.).

Louisiana: west of Meriden, 15 April, 1901, *Canby, Sargent, Trelease & Bush 144* (Phil. Acad. Nat. Sci. Herb.); without definite locality, *Bradbury* (Phil. Acad. Nat. Sci. Herb.); "Upper Louisiana," *Nuttall* (Phil. Acad. Nat. Sci. Herb.), (?) TYPE; without definite locality, *Hale, ex Short Herb.* (Phil. Acad. Nat. Sci. Herb.).

Minnesota: Houston Co., May, 1912, *Freiberg* (Mo. Bot. Gard. Herb.); railroad banks, Perham, Ottertail Co., 20 July, 1912, *Chandonnet* (Mo. Bot. Gard. Herb.).

Iowa: Fayette Co., 3 June, 1894, *Fink 10* (U. S. Nat. Herb.); Iowa City, *Hitchcock* (Mo. Bot. Gard. Herb.); dry

hillsides, Lee Co., 19 May, 1914, *Rev. John Davis 2371, 3822* (Mo. Bot. Gard. Herb.); low ground on prairies, Armstrong, 14 June, 1883, and 5 June, 1898, *Cratty* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Burnside, 1 June, 1899, *Somes C. 3014* (U. S. Nat. Herb.); wet meadows, Decatur Co., 28 May, 1898, *Anderson* (Mo. Bot. Gard. Herb.); dry hills, near Council Bluffs, Nicollet's North-Western Expedition, 16 May, 1839, *Geyer 98* (Phil. Acad. Nat. Sci. Herb., Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); without definite locality, 9 June, 1875, *Arthur* (Mo. Bot. Gard. Herb.).

North Dakota: Conway, 2 July, 1896, *Brannon 193* (Mo. Bot. Gard. Herb.); dry prairie, Grand Forks, 12 June, 1896, *Brannon 232* (Mo. Bot. Gard. Herb.); on level prairie, Rogers, 10 June, 1912, *Bergman 1696* (Mo. Bot. Gard. Herb.); along bottom of open ravine, Adrian, 27 June, 1912, *Bergman 1808* (Mo. Bot. Gard. Herb.); wet prairie, Leeds, 11 June, 1899, *Lunell* (Gray Herb.).

South Dakota: prairies, "Oakwood," 23 May, 1902, *A. G. J.* (Mo. Bot. Gard. Herb.); Brookings, coll. of 1892, *Williams* (U. S. Nat. Herb.); Brookings, 20 June, 1893, *Thornber* (Mo. Bot. Gard. Herb.); Brookings, June, 1905, *White* (Mo. Bot. Gard. Herb.); Sioux Falls, 18 May, 1894, *Thornber* (Mo. Bot. Gard. Herb.); Fort Pierre to Yellowstone River, Raynolds' Expedition to the Headwaters of the Missouri and Yellowstone Rivers, July, 1859, *Hayden* (Mo. Bot. Gard. Herb.); grassy draws on plains, Washabaugh Co., 22 May, 1914, *Over 2088* (U. S. Nat. Herb.); Black Hills, near Fort Meade, 21 June, 1887, *Forwood 231* (U. S. Nat. Herb.); Custer, 16 July, 1892, *Rydberg 827* (Gray Herb.), in part; Hot Springs, 18 June, 1892, *Rydberg 828* (Gray Herb. and U. S. Nat. Herb.); Mayo, 18 June, 1914, *Over 1895* (U. S. Nat. Herb.).

Montana: Miles City, 26 May, 1902, *Blankenship* (Gray Herb.).

Nebraska: one hundred miles above Council Bluffs, 4 June, 1853, *Hayden* (Mo. Bot. Gard. Herb.); Mauvaises Terres, 12 July, 1853, *Hayden* (Mo. Bot. Gard. Herb.); Fremont, 3 June, 1893, *Schenck 6* (Mo. Bot. Gard. Herb.); prairies near Lincoln,

June, 1887, *Webber*, also 10 and 12 May, 1900, *Hedgcock* (Mo. Bot. Gard. Herb.); Minden, 11 June, 1907, *Hapeman* (Mo. Bot. Gard. Herb.); Big Blue and Little Blue Rivers to Big Platte River, June, 1849, *Fendler 71* (Gray Herb.); Republican Valley, Franklin Co., 15 May, 1893, *Laybourn* (Mo. Bot. Gard. Herb.); Hershey, 20 May, 1903, *Mell 46* (U. S. Nat. Herb.); along streams, Halsey, 27 May, 1903, *Mell & Knopff* (Mo. Bot. Gard. Herb.); Platte bottom, Kearney Co., 15 June, 1891, also Cheyenne Co., 3 Aug., 1891, *Rydberg 211* (U. S. Nat. Herb.); Nebraska (?), Stevens' Pacific Railway Expedition (U. S. Nat. Herb. 48724, 48726).

Colorado: near Evans and Greeley, colls. of June, 1907, 1908, and 1909, *E. L. Johnston 439, 441, 443, 445, 460, 546* (Mo. Bot. Gard. Herb.); New Windsor, Weld Co., 4 June, 1901, *Osterhout* (U. S. Nat. Herb. and Phil. Acad. Nat. Sci. Herb.); Fort Lupton, in Platte River bed, 19 May, 1 and 15 June, 1913, *E. L. Johnston 884, 872, 868* (U. S. Nat. Herb.); river flats, Fort Collins, alt. 1525 m., 17 May, 1895, *Crandall 281* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); cañon of the Cache-la-Poudre, 2 June, 1891, *Crandall* (U. S. Nat. Herb.); Denver, Lieut. Wheeler's Expedition, June, 1873, *Wolf 556* (U. S. Nat. Herb.); low meadows on Clear Creek, 23 May, 1870, *Greene 226* (Gray Herb.); near Breckenridge, 22 July, 1906, *Anderson* (Mo. Bot. Gard. Herb.); Horsetooth Gulch, 28 May, 1898, *Crandall 3070* (U. S. Nat. Herb.); wet meadow valley, 20 June, 1873, *Brandegee* (Mo. Bot. Gard. Herb.).

Kansas: Manhattan, coll. of 1884, *Kellerman 8* (Gray Herb.); Manhattan, 15 May, 1887, *Kellerman* (Mo. Bot. Gard. Herb.); Manhattan, 6 May, 1891, *Fritz* (U. S. Nat. Herb.); stony hills, Riley Co., 9 May, 1895, and coll. of 1896, *Norton 303* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Emporia, 29 April, 1890, *Tyler* (Mo. Bot. Gard. Herb.); Cowley, *White* (Mo. Bot. Gard. Herb.); dry prairies, near Osborne City, 14 May, 1894, *Shear 28* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.).

Oklahoma: Huntsville, Kingfisher Co., 29 April, 1896, *Blankenship* (Gray Herb., U. S. Nat. Herb., and Mo. Bot.

Gard. Herb.); Sapulpa, 29 and 30 April, 1895, *Bush 1249, 975* (Mo. Bot. Gard. Herb.); between Fort Cobb and Fort Arbuckle, *Palmer 461* (U. S. Nat. Herb.); without definite locality, 16 April, 1893, *Waugh 275* (Mo. Bot. Gard. Herb.); without locality, *Stevens 34, 50.2A, 120, 134, 146, 163, 179.6A, 210, 233, 286½, 301½, 420H, 469* (Geo. W. Stevens Herb.).

Texas: rich woods, Dallas, March, 1882, *Reverchon 556* (Mo. Bot. Gard. Herb.); on prairie, Dallas, 15 April, 1900, *Bush 606* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); rocky prairies, Fort Worth, 21 April, 1902, *Reverchon* (Mo. Bot. Gard. Herb.); hillsides, Polytechnic, 5 March, 1913, *Ruth 54* (Mo. Bot. Gard. Herb.); Limestone Co., March, 1878, *Joor* (U. S. Nat. Herb.); College Station, Brazos Co., *Ness 2083* (Mo. Bot. Gard. Herb.); sandy prairies, Terrell, 6 April, 1903, *Reverchon 3964* (Gray Herb. and Mo. Bot. Gard. Herb.); Round-top Mountain, Comanche Co., 9 May, 1900, *Eggert* (Mo. Bot. Gard. Herb.); Georgetown, March, 1890, *Bodin 53* (U. S. Nat. Herb); Gillespie Co., *ex Herb. Jermy* (Mo. Bot. Gard. Herb.); New Braunfels, April, 1851, *Lindheimer* (Mo. Bot. Gard. Herb.); in patches on rocky high plains, Upper Guadeloupe, coll. of March, 1846, *Lindheimer 445* (Gray Herb., U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.).

67. S. Willingii Greenm. Ottawa Nat. 25:117. 1911.

An herbaceous perennial, somewhat glaucous; stems erect, 2.5 to 3 dm. high, glabrous, striate, leafy; leaves oblong-lanceolate, 3 to 12 cm. long, .7 to 2 cm. broad, crenate-serrate to pinnately divided into oblong, entire or obtusely dentate lobes obtuse to rounded at the apex, in the early stages floccose-tomentulose along the midrib and lateral nerves beneath and on the margins of the petioles, later glabrate; inflorescence a terminal, rather dense, corymbose cyme; heads 8 to 10 mm. high, radiate; involucre campanulate, calyculate, sparingly floccose-tomentulose, glabrate; bracts of the involucre about 21, linear-lanceolate, 6 to 7 mm. long, acute; ray-flowers about 12, rays yellow; disk flowers numerous, 60 to 70; achenes glabrous.

Distribution: Manitoba to Alberta.

Specimens examined:

Manitoba: gravelly soil, Ninga, 1 June, 1908, *Hales 24* (Geol. Surv. Canada Herb.).

Alberta: near Olds, Aug., 1894, *Willing* (Geol. Surv. Canada Herb. 14843, 6063, fragment and photograph in Field Mus. Herb.), TYPE.

68. S. Smallii Britt. Mem. Torr. Bot. Club **4**:132. 1894; Britton & Brown, Ill. Fl. **3**:479, *fig. 4044*. 1898, and ed. 2, 546, *fig. 4630*. 1913; Heller, Cat. N. Am. Pl. 147. 1898, and ed. 2, 231. 1900; Britton, Manual 1028. 1901, and ed. 2, 1905; Small, Fl. Southeastern U. S. 1304. 1903, and ed. 2, 1913; Greenm. in Gray, Manual, ed. 7, 854. 1908.

S. Balsamitae Ell. Sketch **2**:330. 1824, not Muhl.

S. aureus var. *Balsamitae* Gray, Syn. Fl. N. Am. **1**[2]:391. 1884, and ed. 2. 1886, in part; Chapman, Fl. Southern U. S. 245. 1860, ed. 2, 1889, and ed. 3, 266. 1897.

S. aureus var. *angustifolius* Britt. Mem. Torr. Bot. Club **2**:39. 1890, not *S. angustifolius* Willd.

S. Earlei Small, Bull. Torr. Bot. Club **25**:147. 1898.

(?) *S. Memmingeri* Britt. Bull. Torr. Bot. Club **25**:147. 1898.

An herbaceous perennial; stems one to several, erect from a common base, 2 to 6 dm. high, conspicuously and permanently woolly tomentose at the base and in the leaf-axils; lower leaves long-petiolate, narrowly oblong-oblanceolate, 1.5 to 13 cm. long, 1 to 3 cm. broad, obtuse to rounded at the apex, crenate to serrate-dentate, narrowed at the base into the petiole; petioles 1.5 to 18 cm. long; stem-leaves petiolate and sublyrate to sessile and more or less pinnatisect; inflorescence a terminal many-headed corymbose cyme; heads usually very numerous, relatively small, 7 to 10 mm. high, radiate; involucre campanulate, sparingly calyculate; bracts of the involucre 13 to 21, linear-lanceolate, 5 to 6 mm. long, glabrous; ray-flowers 8 to 13, rays yellow; disk-flowers numerous; achenes usually but not always hispidulous along the angles.

Distribution: southern Pennsylvania to Florida.

Specimens examined:

Pennsylvania: Tullytown, Bucks Co., 15 May, 1896, *Crawford* (Phil. Acad. Nat. Sci. Herb.); Westtown, Chester Co., 22 June, 1895, *Crawford* (Phil. Acad. Nat. Sci. Herb.); near Mt. Hope, in red sandstone, Lancaster Co., 24 June, 1901, *Heller* (Mo. Bot. Gard. Herb.).

Maryland: Baldfriar, Cecil Co., 4 July, 1907, *Bartram* (Phil. Acad. Nat. Sci. Herb.); Norbeck, 25 June, 1895, *Mearns* (U. S. Nat. Herb.); between Garrett Park and Kensington, 8 June, 1907, *Steele* (U. S. Nat. Herb.); field above Cabin John, 7 June, 1908, *Steele* (U. S. Nat. Herb.); dry slopes, Chevy Chase Lake, 30 May, 1911, *Standley 5983* (U. S. Nat. Herb.).

District of Columbia: vicinity of Washington, 10 June, 1877, and 27 May, 1878, *Ward* (U. S. Nat. Herb. 131112 in part, and 131111); Queen's Chapel Road, 12 June, 1888, *Burgess* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Garrett Park, June, 1894, and in open thickets, Brookland, 6 June, 1895, *Holm* (Mo. Bot. Gard. Herb.); Rock Creek Park, 26 May, 1895, *Pollard 285* (U. S. Nat. Herb.); vicinity of Washington, 25 May, 1896, *Steele* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); wooded side-hill of Piney Branch, Rock Creek Park, 27 May, 1899, *Maxon 140* (U. S. Nat. Herb.); Chevy Chase, 16 May, 1905, *House 721* (Mo. Bot. Gard. Herb.); Tenallytown, 14 June, 1871, *F. Blanchard* (Mo. Bot. Gard. Herb.).

Virginia: Fairfax Co., 7 June, 1902, *G. S. Miller* (U. S. Nat. Herb.); West End, Fairfax Co., 30 June, 1907, *Steele* (U. S. Nat. Herb.); dry woods, Falls Church, 30 May, 1912, *Ruth 164* (U. S. Nat. Herb.); open woods, Bluemont, Loudon Co., 31 May, 1915, *Standley 11621* (U. S. Nat. Herb.); dry fields, Hampton, 19 May, 1903, *G. S. Miller* (U. S. Nat. Herb.); Richmond, *de Chalmont* (U. S. Nat. Herb.); near Suffolk, Nansemond Co., 19 May, 1898, *Kearney 1271* (U. S. Nat. Herb.); near Branchville, Southampton Co., 12 June, 1893, *Heller 958* (Phil. Acad. Nat. Sci. Herb. and Mo. Bot. Gard. Herb.); in old fields, vicinity of Belfield, 21 May, 1904, *Meyncke* (U. S. Nat. Herb.); Appomattox, *Rumer* (U. S. Nat. Herb.); pine

woods, Bedford Co., *A. H. Curtiss* (Gray Herb. and Mo. Bot. Gard. Herb.); Peaks of Otter, 6 June, 1890, *Brown, Hogg, Vail, Timmerman & Britton* (U. S. Nat. Herb. and Greene Herb.); between Fall Creek and Danville, 3 June, 1891, *Small & Heller 234* (U. S. Nat. Herb.); vicinity of Marion, Smyth Co., alt. 640 m., 6 June, 1892, *N. L. and E. Britton & Vail* (Phil. Acad. Nat. Sci. Herb.); Hutton's Branch, East Marion, alt. 760 m., 6 June, 1892, *Small* (Mo. Bot. Gard. Herb.); along Comer Creek, 15 June, 1892, alt. 915 m., *Small* (U. S. Nat. Herb.).

North Carolina: Weldon, *Williamson* (C. S. Williamson Herb.); vicinity of Heilig's Mill, Rowan Co., 4–9 June, 1891, *Small & Heller 490* (Mo. Bot. Gard. Herb.); in woods, near Faith, 27 May, 1891, *Heller 10263* (Mo. Bot. Gard. Herb.); Statesville, *Hyams* (Mo. Bot. Gard. Herb.); near Hickory, alt. 550 m., 23 June, 1893, *Heller* (Phil. Acad. Nat. Sci. Herb.); east of Blowing Rock, Caldwell Co., 24 June, 1893, alt. 1065 m., *Heller* (Phil. Acad. Nat. Sci. Herb.); dry open woods and clearings, Biltmore, 14 June, 1900, *Mohr* (U. S. Nat. Herb.); vicinity of Asheville, May, 1888, *McCarthy* (U. S. Nat. Herb.); dry woods and waste places, Biltmore, 20 May, 1896, *Biltmore Herb. 1233* (Mo. Bot. Gard. Herb.); old fields, Biltmore, 11 June, 1897, *Biltmore Herb. 1233b* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); "Half Way," Black Mountain, 27 June, 1902, *Harshberger 79* (U. S. Nat. Herb. and Phil. Acad. Nat. Sci. Herb.); Tryon, Polk Co., 22 May, 1899, *Churchill* (Gray Herb.); foot of mountain, Tryon, 22 May, 1897, *Townsend* (U. S. Nat. Herb.); Sunburst, Haywood Co., alt. 975 m., 19 June, 1910, *House 4339* (U. S. Nat. Herb.); without definite locality, June, 1879, *Gray, Sargent, Redfield & Canby* (Gray Herb.); on mountain bluff, *Gray & Carey* (Gray Herb.), small form.

South Carolina: Table Rock, Pickens Co., *Buckley* (Gray Herb.); dry woods and fields, Fort Hill, Oconee Co., 30 April, 1906, *House 1994* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); without locality, May, 1867, *Ravanel* (Gray Herb.).

Georgia: Gainesville, 10 May, 1879, *Trelease* (Mo. Bot. Gard. Herb.); dry woods on highest summit of Pigeon Moun-

tains, Walker Co., alt. 710 m., 1 Aug., 1900, *Harper 338* (U. S. Nat. Herb.); Lookout Mountain, July, 1898, *Ruth 673* (U. S. Nat. Herb.) and *704* (Mo. Bot. Gard. Herb.); Lookout Mountain, 25 May, 1901, *Trelease* (Mo. Bot. Gard. Herb.); Thompson's Mills and vicinity, Gwinnett Co., 26 April, 1908, *Allard 267, 268* (U. S. Nat. Herb.); Stone Mountain, 13 May, 1901, *A. H. Curtiss 6780* (Gray Herb., U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.); Stone Mountain, 23 May, 1897, and 17 May, 1899, *Eggert* (Mo. Bot. Gard. Herb.); rocky places, Covesprings, 15 May, 1881, *Mohr* (U. S. Nat. Herb.); Tallapoosa, April and May, 1900, *Way 30* (U. S. Nat. Herb.); Lagrange, 16 May, 1905, *Tracy 8944* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); without definite locality, *Boykin* (Phil. Acad. Nat. Sci. Herb.).

Alabama: Wedowee, Randolph Co., 28 May, 1874, *Mohr* (U. S. Nat. Herb.); Auburn, Lee Co., colls. of 1897 and 1898, *Earle & Baker* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); dry, open places, Auburn, 10 June, 1901, *Earle* (Gray Herb.); Cullman, May, 1886, and June, 1895, *Mohr* (U. S. Nat. Herb.); without definite locality, June, 1889, *Miss Emily Mohr* (U. S. Nat. Herb. 782485).

Florida: without definite locality, *Chapman* (Gray Herb. and Mo. Bot. Gard. Herb.).

Tennessee: dry ground, Knoxville, May, 1898, *Ruth 672* (U. S. Nat. Herb.); dry sterile grounds, Knoxville, June, 1898, *Ruth 703* (Mo. Bot. Gard. Herb.).

This species, *S. Smallii*, and the following, *S. pauperculus*, are, as a rule, easily distinguished by the taller stems, longer leaves, more numerous and somewhat smaller heads of the former; but in southeastern Pennsylvania and in Maryland occasional forms occur, for example, Crawford's specimen from Tullytown, 15 May, 1896, and Small's specimen from Mt. Hope, 24 June, 1901, which are somewhat intermediate. These two specimens seem to the writer to possess rather more the characters of *S. Smallii* than of *S. pauperculus*. Moreover, Crawford's specimen from Westtown, Pa., 22 June, 1895, is a perfect match for Heller's specimen, No. 10263,

from North Carolina, as well as certain other collections from the southern states. The range of *S. Smallii* may be said therefore to extend to southern Pennsylvania.

69. S. pauperculus Michx.[1] Fl. Bor. Am. **2**:120. 1803; Pursh, Fl. Am. Sept. **2**:529. 1814, and ed. 2, 1816; DC. Prodr. **6**:432. 1837; Britton & Brown, Ill. Fl. **3**:545, *fig. 4629*. 1913.

S. Balsamitae Muhl. ex. Willd. Sp. Pl. **3**:1998. 1804; Pursh, Fl. Am. Sept. **2**:530. 1814, and ed. 2, 1816, excl. synonymy; Beck, Bot. Northern and Middle States 200. 1833, excl. synonym; Darlington, Fl. Cest. 497. 1837; Heller, Cat. N. Am. Pl. 146. 1898, and ed. 2, 229. 1900; Britton & Brown, Ill. Fl. **3**:479, *fig. 4043*. 1898; Britton, Manual 1027. 1901, and ed. 2, 1905, in major part; Greenm. in Rhodora **3**:5. 1901; Monogr. Senecio, I. Teil, 23. 1901, and in Engl. Bot. Jahrb. **32**:19. 1902; Porter, Fl. Penn. 339. 1903; Keller & Brown, Handb. Fl. Phil. and Vicinity 343. 1905; Greenm. in Gray, Manual, ed. 7, 854. 1908; Small, Fl. Lancaster County 310. 1913.

S. aureus var. *Balsamitae* Torr. & Gray, Fl. N. Am. **2**:442. 1843, in part; Torr. Nat. Hist. N. Y., pt. 2, Botany **1**:402. 1843; Britton, Cat. Pl. N. J. 54. 1881; *ibid.* 150. 1890; Gray, Syn. Fl. N. Am. **1**[2]:391. 1884, and ed. 2, 1886, in part; Macoun, Cat. Canadian Pl. 265. 1884, in major part.

S. Balsamitae var. *praelongus* Greenm. Rhodora **3**:6. 1901; Graves et al. Conn. Geol. and Nat. Hist. Surv. Bull. No. 14, p. 404. 1910.

An herbaceous perennial, somewhat tomentulose, particularly at the base of the stem and in the leaf-axils, to glabrous; stems erect or nearly so, one to several from a common base, 1 to 4 dm. high; lower leaves petiolate, narrowly oblong oblanceolate, including the petiole 2 to 18 cm. long, .5 to 2 cm. broad, rounded to obtuse at the apex, crenate to serrate-dentate, gradually narrowed at the base; stem-leaves petiolate and sublyrate to sessile and pinnatisect; inflorescence a terminal few to several-headed corymbose cyme, occasionally reduced to a single head; heads 5 to 10 mm. high, radiate; in-

[1]The name *pauperculus* is here maintained for this species instead of *Balsamitae* largely on the statement of Dr. Otto Kuntze, Rev. Gen. Pl. 1: CXXXIV, CXXXV. 1891.

volucre campanulate, calyculate; bracts of the involucre (13–) 21, linear-lanceolate, 3 to 6 mm. long, usually glabrous; ray-flowers 8 to 13, rays yellow; disk-flowers numerous; achenes glabrous or hirtellous along the angles.

Distribution: Labrador to Minnesota, south to Virginia and Missouri.

Specimens examined:

Labrador: hills near lighthouse, Forteau, 23 Aug., 1894, *Waghorne 29* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); boggy spots, and in wet moss by spring, Blanc Sablon, Strait of Belle Isle, 1 Aug., 1910, *Fernald & Wiegand 4185, 4186* (Gray Herb.); wet limestone and calcareous sandstone terraces, Blanc Sablon, 6 Aug., 1910, *Fernald & Wiegand 4178* (Gray Herb.).

Newfoundland: damp limestone barrens, near sea-level, Pointe Riche, 4 Aug., 1910, *Fernald & Wiegand 4176* (Gray Herb.); dry rocky limestone barrens, near sea-level, Ingornachoix Bay, 4 Aug., 1910, *Fernald & Wiegand 4177* (Gray Herb.); barrens at the base of serpentine tablelands, Bonne Bay, 27 Aug., 1910, *Fernald & Wiegand 4179* (Gray Herb.); crests of sea cliffs, Western Head, New Worlds Island, Notre Dame Bay, 20 July, 1911, *Fernald & Wiegand 6407* (Gray Herb.); boggy places on hill, southwest of Tilt Cove, Notre Dame Bay, 25 Aug., 1911, *Fernald & Wiegand 6412* (Gray Herb.); Fogo Island, 27 July, 1903, *Sornborger* (Gray Herb.); ledges and talus, north bank of river below Grand Falls, 3 July, 1911, *Fernald & Wiegand 6402* (Gray Herb.); open bogs among the hills, Grand Falls, 23 July, 1911, *Fernald & Wiegand 6411* (Gray Herb.); bog, Grand Falls, 5 July, 1911, *Williamson* (C. S. Williamson Herb.); shingly beach, north bank of river, below Grand Falls, 22 July, 1911, *Fernald & Wiegand 6406* (Gray Herb.); gravelly river bank, Glenwood, 12 and 13 July, 1911, *Fernald & Wiegand 6403, 6404* (Gray Herb.); Tilton Harbor to Barred Island, 31 July, 1903, *Sornborger* (Gray Herb.); Barred Island, 13 Aug., 1903, *Sornborger* (Gray Herb.); swamp, foot of Helmet, Holyrood, 22 Aug., 1894, *Robinson & Schrenk* (Gray Herb.); near confluence

of Exploits River and Badger Brook, 13 Aug., 1894, *Robinson & Schrenk* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); sandy clearing, Mary Anne Brook, 14 July, 1911, *Fernald & Wiegand 6410* (Gray Herb.); dry bog, Millertown Junction, 7 July, 1911, *Fernald & Wiegand 6408* (Gray Herb.); damp talus slopes of the marble region between Mt. Musgrave and Humber Mouth (Bay of Islands Station), 18 July, 1910, *Fernald & Wiegand 4183* (Gray Herb.); gravelly beach, Middle Birchy Pond, 11 July, 1910, *Fernald & Wiegand 4182* (Gray Herb.); open tundra along Junction Brook, 12 and 13 July, 1911, *Fernald & Wiegand 6409* (Gray Herb.); boggy places on the hill back of Summerside, 11 July, 1910, *Fernald & Wiegand 4181* (Gray Herb.); open peat bog among Silurian hills, back of Birchy Cove (Curling), 8 July, 1910, *Fernald & Wiegand 4180* (Gray Herb.); serpentine and magnesian limestone barrens, northeastern bases and slopes of Blomidon (Blow-me-down) Mountains, 24 July, 1910, *Fernald & Wiegand 4184* (Gray Herb.); barrens at the base of serpentine table-lands, Bonne Bay, 27 Aug., 1910, *Fernald & Wiegand 4187* (Gray Herb.); fields, Coal River, 14 July, 1896, *Waghorne 15* (Gray Herb.), and 16 July, 1896, *Waghorne 12* (Mo. Bot. Gard. Herb.); sandy shore, Grand Lake, Bay of Islands, 11 Aug., 1896, *Waghorne 45* (Gray Herb.); sea-bank, near Chimney Cove, Bay of Islands, *Waghorne 8* (Gray Herb.); Bay of Islands, 24 June, 1895, *Waghorne 23* (Mo. Bot. Gard. Herb.), and 18 July, 1895, *Waghorne* (U. S. Nat. Herb.); open bog, Bay of Islands, 23 July, 1908, *Eames & Godfrey 8131* (Gray Herb.).

Quebec: rocky shores, River de Brig, Anticosti, 10 July, 1883, *Macoun* (U. S. Nat. Herb.); ravine, Mt. Albert, Gaspé Co., 26 July, 1881, *ex Herb. J. A. Allen* (U. S. Nat. Herb.); crevices and talus of serpentine, gulch north of Lac au Diable, Mt. Albert, Gaspé Co., alt. 750–950 m., 25 July, 1906, *Collins & Fernald 752* (Gray Herb.); cold wet rocks, head of au Diable, alt. 950 m., 8–15 Aug., 1905, *Collins & Fernald* (Gray Herb.); calcareous marl, Trout Pond, mouth of Grand River, Gaspé Co., 11–15 Aug., 1904, *Collins, Fernald & Pease* (Gray

Herb.); banks of Grand River, 20 June–10 July, 1903, *Richards* (Gray Herb.); banks of Grand River, Gaspé Co., 30 June–3 July, 1904, *Fernald* (Gray Herb.); gravelly beaches and flats, also wet alluvial shores, between Baldé and Baie des Chaleurs, Bonaventure River, 5, 6 and 7 Aug., 1904, *Collins, Fernald & Pease* (Gray Herb.); Gatineau River, 6 Sept., 1894, *Macoun* (Mo. Bot. Gard. Herb.); gravel beaches near the mouth of Dartmouth River, 26 and 27 Aug., 1904, *Collins, Fernald & Pease* (Gray Herb.), form with proliferous heads, also with both radiate and discoid heads.

Ontario: Plevna, 20 June, 1902, *Fowler* (Gray Herb.); sand ridges north of Sarnia, Lambton Co., 13 June, 1895, *Dodge 109* (U. S. Nat. Herb.); region of Lake Superior, *Macoun 52* (Mo. Bot. Gard. Herb.).

Maine: sunny alluvium, Fort Kent, 6 July, 1904, *Fernald* (Gray Herb.); rocky ledges, Fort Kent, 19 July, 1908, *Mackenzie 3600* (Mo. Bot. Gard. Herb.); rocky river-flat, Fort Kent, 10 July, 1908, *Mackenzie 3418* (Mo. Bot. Gard. Herb.); gravelly shores, Fort Fairfield, 5 July, 1893, *Fernald 71* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Pamedumcook Lake, 10 Aug., 1881, *Chickering* (Gray Herb. and U. S. Nat. Herb.); rocks in river, Orono, 1 July, 1890, *Fernald* (Gray Herb.).

New Hampshire: Sumner's Falls, 27 June, 1898, *Eggleston* (Mo. Bot. Gard. Herb.), and 25 June, 1902, *Eggleston 2804* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.).

Vermont: Colchester, coll. of 1842, *Oakes* (Gray Herb., U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.); Winooski High Bridge, 14 June, 1881, *E. & C. E. Faxon* (Gray Herb.); Barnet, 20 June, 1884, *F. Blanchard* (Mo. Bot. Gard. Herb.); Manchester, 27 June, 1898, *Day 210* (Gray Herb. and U. S. Nat. Herb.); Bellows Falls, coll. of 1901, *W. H. Blanchard* (Gray Herb.); Putney, 8 June, 1902, *W. H. Blanchard* (Gray Herb.); without definite locality, *Robbins* (Phil. Acad. Nat. Sci. Herb.).

Massachusetts: Danvers, without date, *Oakes* (Phil. Acad. Nat. Sci. Herb.); without definite locality, *Oakes* (Gray

Herb.); rocky woods near summit of Blue Hill, Milton, *Rich* (Gray Herb.).

New York: Watertown, Jefferson Co., coll. of 1834, *Torr. & Gray, Fl. N. Am.* (Gray Herb.); rocky banks of Blue River, Watertown, 3 July, 1857, *ex Herb. Wm. Boott* (Gray Herb.); Dexter, *ex Herb. Geo. Vasey* (Gray Herb.); Oneida Co., coll. of 1864, *Paine* (Gray Herb.); sandy bog, near Syracuse, 22 June, 1882, *Sheldon* (Phil. Acad. Nat. Sci. Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.); tamarack swamp, near Syracuse, 28 May, 1902, *House* (U. S. Nat. Herb.).

New Jersey: low meadows, Newfoundland, Morris Co., 14 June, 1908, *Mackenzie 3119* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); dry woods, Chatham, 30 May, 1903, *Mackenzie 182* (Mo. Bot. Gard. Herb.); dry fields, Murray Hill, Union Co., 30 May, 1906, *Mackenzie 2044* (Mo. Bot. Gard. Herb.); Somerset Co., *Perry* (Mo. Bot. Gard. Herb.).

Pennsylvania: Laanna, Pike Co., 9 June, 1906, *Long* (Phil. Acad. Nat. Sci. Herb.); Allentown, 18 June, 1899, *Dowell* (U. S. Nat. Herb.); Manganese Park, southeast of Allentown, 8 June, 1908, near Mountainville, 13 June, 1908, and 13 June, 1914, also near Lanark, 24 May, 1908, *Pretz 1232, 1253, 6636, 1197* (Phil. Acad. Nat. Sci. Herb.); Nockamixon, Bucks Co., June, 1892, *Crawford* (Phil. Acad. Nat. Sci. Herb.); Rockhill, 19 June, 1892, *MacElwee* (Phil. Acad. Nat. Sci. Herb.); Perkasie, June, 1881, *Fretz* (Phil. Acad. Nat. Sci. Herb.); Tunnel Hill near Perkasie, 31 May, 1903, *MacElwee* (Phil. Acad. Nat. Sci. Herb.); Perkasie, 30 May, 1906, *Brown* (Phil. Acad. Nat. Sci. Herb.); near Sellersville, 7 June, 1893, *Porter* (Phil. Acad. Nat. Sci. Herb.); along Perkiomen Creek, near Sellersville, 2 June, 1899, *MacElwee 408* (Phil. Acad. Nat. Sci. Herb.); Argus, 6 June, 1898, *Fretz* (Phil. Acad. Nat. Sci. Herb.); Aquetong, 30 May, 1910, *Keller* (Phil. Acad. Nat. Sci. Herb.); Sumneytown, 30 May, 1903, *Jahn,* and 30 May, 1905, *Keller* (Phil. Acad. Nat. Sci. Herb.); Sumneytown, 30 May, 1903, *Williamson* (C. S. Williamson Herb.); dry fields along Wissahickon Creek, Penllyn, 12 June, 1909, *Long* (Phil. Acad. Nat. Sci. Herb.); between Hillside and Ardsley, 12 Oct., 1907, *Long*

(Phil. Acad. Nat. Sci. Herb.); near Noble, 13 June, 1912, *Long 7085* (Phil. Acad. Nat. Sci. Herb.); Layfayette, 2 June, 1895, *Keller, Jahn*, also *Uselma C. Smith 816* (Phil. Acad. Nat. Sci. Herb.); Layfayette, 5 June, 1897, *Jahn* (Phil. Acad. Nat. Sci. Herb.); serpentine barrens, Newtown, Delaware Co., 25 June, 1901, *Benj. H. Smith* (Phil. Acad. Nat. Sci. Herb.); serpentine barrens, near Newtown Square, 12 June, 1899, *MacElwee 491, 505* (Phil. Acad. Nat. Sci. Herb.); Williamson, 4 June, 1891, *Crawford*, 28 July, 1899, *MacElwee 999*, and 11 June, 1911, *Pennell 2764, 3641* (Phil. Acad. Nat. Sci. Herb.); Media, 30 May, 1896, *Githens* (Phil. Acad. Nat. Sci. Herb.); Elwyn, 8 June, 1890, *Brinton*, and 9 June, 1896, *ex Herb. Beringer* (Phil. Acad. Nat. Sci. Herb.); Wawa, 5 July, 1908, *Pennell 15*, and 9 June, 1896, *Bartram* (Phil. Acad. Nat. Sci. Herb.); Chester Heights, 23 June, 1907, *Pennell* (Phil. Acad. Nat. Sci. Herb.); Mineral Hill, 9 June, 1911, and 6 Sept., 1908, *Pennell 2719, 610* (Phil. Acad. Nat. Sci. Herb.); Fawkes Run, 30 May, 1909, and 10 June, 1911, *Pennell 1365, 2742* (Phil. Acad. Nat. Sci. Herb.); Phoenixville, Chester Co., coll. of 1865, *Martindale* (Phil. Acad. Nat. Sci. Herb.); Sugartown Barrens, 22 July, 1908, *Pennell 293*, and serpentine ridge, northwest of Sugartown, 30 May, 1909, *Pennell 1379* (Phil. Acad. Nat. Sci. Herb.); serpentine ridge, Willistown, 28 May, 1904, *Painter 673* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Willistown barrens, 24 May, 1908, *Williamson* (Phil. Acad. Nat. Sci. Herb.); serpentine ridge, Chester Co., June, 1882, *Windle* (U. S. Nat. Herb.); Westtown, 22 June, 1895, *Crawford* (Phil. Acad. Nat. Sci. Herb.); Fern Hill, 7 June, 1909, *Long* (Phil. Acad. Nat. Sci. Herb.); West Chester, coll. of 1828, *Wm. Darlington* (Phil. Acad. Nat. Sci. Herb.); West Chester, without date, *David Townsend*, and 29 May, 1909, *Pennell 1344* (Phil. Acad. Nat. Sci. Herb.); Sconnelltown, 29 July, 1908, *Pennell 343* (Phil. Acad. Nat. Sci. Herb.); Nottingham Barrens, 22 May, 1912, *Pennell & Long 3715, 7538* (Phil. Acad. Nat. Sci. Herb.); Cedar Barrens, Chester Co., 30 May, 1909, and 10 June, 1911, *Pennell 1395, 2760* (Phil. Acad. Nat. Sci. Herb.); high above Muddy Run, 5 July, 1904, *Crawford* (Phil.

Acad. Nat. Sci. Herb.); Pequea, June, 1893, *Eby* (Mo. Bot. Gard. Herb.); near Mt. Hope, 5 June, 1900, *Heller* (Gray Herb. and U. S. Nat. Herb.); Conewago, 28 May, 1889, *Heller* (Gray Herb.); in wet meadow, Rock Hill, 31 May, 1903, *MacElwee* (Phil. Acad. Nat. Sci. Herb.); Rawlinsville, coll. of 1884, *ex Herb. Galen* (Gray Herb.); Fulton, June, 1906, *Carter* (Phil. Acad. Nat. Sci. Herb.); near Pleasant Grove, in serpentine barrens, 5 June, 1901, *Heller* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); dry ground, near Round Top, Gettysburg, Adams Co., 24 June, 1894, *MacElwee* (Phil. Acad. Nat. Sci. Herb.); York Co., 3 June, 1895, *Glatfelter* (Mo. Bot. Gard. Herb.); Ohiopyle, Fayette Co., 3–8 June, 1905, *Brown, Crawford & Van Pelt* (Phil. Acad. Nat. Sci. Herb.).

Delaware: dry serpentine barrens, near Centerville, 15 June, 1866, and 10 July, 1868, *Commons* (Phil. Acad. Nat. Sci. Herb.); on serpentine, south of Mount Cuba, 18 June, 1914, *Pennell 1510* (Phil. Acad. Nat. Sci. Herb.); near Cooch's Mill, 29 May, 1896, *Commons* (Phil. Acad. Nat. Sci. Herb. 543180), in part.

Maryland: Rockville, 30 May, 1905, *Painter 1366* (Mo. Bot. Gard. Herb.); Brooklyn, 30 May, 1899, *Thurston* (U. S. Nat. Herb.); Laurel, 23 May, 1897, *Knoulton* (U. S. Nat. Herb.); College Park, 28 May, 1900, *Stewart* (Mo. Bot. Gard. Herb.); Mountain Lake Park, Garrett Co., *Shreve 560* (U. S. Nat. Herb.).

Virginia: on rocks in moss, Great Falls, June, 1903, *Painter 357* (U. S. Nat. Herb.).

Michigan: "L. Superior, Pic to Sault", *Loring* (Gray Herb.); Macinaw City, 12 Aug., 1890, *Wheeler* (Gray Herb.); Thunder Bay Island, Alpena Co., 18 July, 1895, *Wheeler* (Gray Herb.); North Point, Alpena Co., 3 July, 1895, *Wheeler* (U. S. Nat. Herb.); dry woods near Hillman, Montmorency Co., 7 July, 1895, *Wheeler* (U. S. Nat. Herb.); Clarkston, 30 June, 1888, *Hicks* (U. S. Nat. Herb.); marl beds on Parkdale Farm, colls. of 1912, 1913, and 1914, *Farwell 2652, 2653, 3491, 3659, 3660* (Mo. Bot. Gard. Herb.).

Ohio: Marblehead Peninsula, 20 May, 1895, *Moseley* (U. S. Nat. Herb.).

Indiana: Mineral Springs, 14 June, 1911, *Nieuwland 2657* (Mo. Bot. Gard. Herb.); moist sands and swales, Pine, 12 June, 1897, *Umbach* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); sandy soil, Edgmoor, Lake Co., 13 June, 1891, *Moffatt 451* (Field Mus. Herb.); prairie, Roby, 18 June, 1910, *Lansing 2784* (U. S. Nat. Herb.).

Minnesota: Center City, June, 1892, *Taylor* (U. S. Nat. Herb.); damp places near Minneapolis, June, 1892, *Burglehaus* (Mo. Bot. Gard. Herb.); without definite locality, July, 1899, *Woods* (U. S. Nat. Herb.); without locality, June, 1849, *Dr. Sykes* (Mo. Bot. Gard. Herb.).

Wisconsin: "N. W. America", *Long* (Mo. Bot. Gard. Herb.).

Illinois: in moist sandy soil near Lake Michigan, Beach, 16 June, 1907, *Greenman 1987, 2015* (Mo. Bot. Gard. Herb.); rich meadow, Beverly Hills, 6 June, 1903, *Chase 2066* (U. S. Nat. Herb.); Morgan Park, 27 May, 1907, *Dixon & Gage 710* (U. S. Nat. Herb.).

Missouri: near Mark Twain's Cave, Ralls Co., 5 May, 1914, *Rev. John Davis 2333* (Mo. Bot. Gard. Herb.).

Var. **firmifolius** (Greenm.) comb. nov.

S. Balsamitae var. *firmifolius* Greenm. Rhodora **7**:244. 1905.

Stems .5 to 2.5 dm. high, simple or branched, more or less tufted; lower leaves mostly short-petiolate, subrotund, oblong-elliptic to oblong-oblanceolate, .5 to 4 cm. long, 5 to 20 mm. broad, crenate-dentate to sublyrately pinnatifid, at first as well as the stem somewhat tomentulose, later more or less glabrate and thickish or firm in texture; upper stem-leaves sessile and pinnatisect to linear and bracteiform.

Distribution: in limestone detritus, crest of Les Murailles, Percé, Gaspé Co., 17 Aug., 1904, *Collins, Fernald & Pease* (Gray Herb.), TYPE; limestone detritus, Mont Rouge, Percé, Gaspé Co., 23 July, 1905, *Collins & Fernald* (Gray Herb.); limestone detritus, Cap Barré, Percé, Gaspé Co., 23 July,

1905, *Collins & Fernald 147* (Gray Herb. and U. S. Nat. Herb.); limestone shingle near summit of Baldé, Bonaventure Co., 5, 6, and 8 Aug., 1904, *Collins, Fernald & Pease* (Gray Herb.); wet red sandstone bluffs and steep slopes, between Baldé and the Baie des Chaleurs, Bonaventure River, 5, 6, and 8 Aug., 1904, *Collins, Fernald & Pease* (Gray Herb.); ledgy banks of the Restigouche River, Metapedia, 19 July, 1904, *Collins & Fernald* (Gray Herb.). The last three specimens cited are transitional forms between the variety and the species.

70. S. flavovirens Rydb. Bull. Torr. Bot. Club **27**:181, *pl. 5, fig. 4.* 1900, mainly; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902.

S. fulgens Rydb. Bull. Torr. Bot. Club **27**:177, *pl. 6, fig. 13.* 1900, not. Nichols.

S. Rydbergii Nels. in Coulter & Nelson, Manual Cent. Rocky Mountains 582. 1909.

S. Balsamitae Rydb. Mem. N. Y. Bot. Gard. **1**:446. 1900, mainly, not Muhl.; Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains 583. 1909, not Muhl.

S. flavulus Rydb. Fl. Colo. 397. 1906, in part, not Greene.

An herbaceous perennial, pale or yellowish green in the dried state, glabrous or slightly white-tomentulose along the margins of the petioles near their base and in the axils of the leaves; stems erect, 2 to 5 dm. high; lower leaves petiolate, oblanceolate to oval, 1 to 6 cm. long, .5 to 2 cm. broad, gradually narrowed into the petiole to abruptly constricted at the base, crenate to coarsely and unequally dentate, obtuse or rounded at the apex, glabrous on both surfaces; stem-leaves petiolate and more or less lyrate to sessile and pinnatisect; inflorescence a terminal few-headed corymbose cyme; heads 7 to 9 mm. high, radiate; involucre campanulate, calyculate; bracts of the involucre 13 to 21, linear-lanceolate, 5 to 7 mm. long, pale or yellowish green and glabrous except at the brownish penicillate tip, becoming thickish in texture; ray-flowers 10 to 12, rays bright yellow; disk-flowers numerous; achenes glabrous or slightly hirtellous along the angles.

Distribution: British Columbia, south to Colorado and Idaho.

Specimens examined:

British Columbia: Field, 12 July, 1904, *Farr* (Univ. Penn. Herb.); Ottertail Drive, near Field, 15 July, 1905, *Farr 817, 818* (Univ. Penn. Herb.); border of an alkali marsh, Similkameen River, 10 June, 1905, *Macoun 69356* (Gray Herb.); Lower Fraser River, N. Lat. 49°, Oregon Boundary Commission, coll. of 1859, *Dr. Lyall* (Gray Herb.).

Montana: Big Fork, Aug., 1908, *Mrs. Joseph Clemens* (Field Mus. Herb. and Mo. Bot. Gard. Herb.).

Yellowstone National Park: Mammoth Hot Springs, 5 July, 1899, *Blankenship* (Gray Herb.); about willow clumps on river bottom, Snake River, 12 Aug., 1899, *A. & E. Nelson 6402* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Fitzgerald's Ranch, near Gardiner Mountain, 3 July, 1902, *Mearns 1493* (U. S. Nat. Herb. and Field Mus. Herb.).

Wyoming: low ground, Adam's Ranch, Jackson's Hole, 15 July, 1901, *Merrill & Wilcox 967* (U. S. Nat. Herb.); sandy soil, Blue Lakes on Wind River, 6 July, 1881–82, *Fairwood* (U. S. Nat. Herb.); Wind River, Aug., 1894, *A. Nelson 760* (Gray Herb. and U. S. Nat. Herb.); Horse Creek, coll. of 1893, *A. Nelson 100* (U. S. Nat. Herb.); Green River, 26 July, 1894, *A. Nelson 1036* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Dale Creek, near Sherman, 29 July, 1884, *Letterman* (Mo. Bot. Gard. Herb.); Evanston, 10 July, 1897, *Williams* (U. S. Nat. Herb.); La Barge, Uinta Co., 18 July, 1894, *Stevenson 201* (U. S. Nat. Herb.); Myer's ranch, Bear River, south of Evanston, alt. 2285–2440 m., 26 July, 1902, *Pammel & Blackwood 4044* (Mo. Bot. Gard. Herb.).

Colorado: N. Lat. 39–41°, coll. of 1862, *Hall & Harbour 332*, in part (Phil. Acad. Nat. Sci. Herb. and Mo. Bot. Gard. Herb.), and *115*, in part (Gray Herb.); Colorado Springs, May, 1878, *Jones* (U. S. Nat. Herb. 223024, in part).

Idaho: open grassy stream lands, Mackay, Custer Co., 1 Aug., 1911, *Nelson & Macbride 1500* (Mo. Bot. Gard. Herb.); Arco, 19 June, 1893, *E. Palmer 193* (U. S. Nat. Herb.).

Var. **thomsoniensis** (Greenm.) comb. nov.

S. Balsamitae var. *thomsoniensis* Greenm. Ottawa Nat. **25**:116. 1911.

S. Balsamitae Greenm. Ottawa Nat. **25**:116. 1911, not Muhl.

Stems 1.2 to 4.5 dm. high, at first floccose-tomentulose later more or less glabrate; lower leaves oblong-oblanceolate, the blade 1 to 7 cm. long, 5 to 12 mm. broad, rounded or obtuse at the apex, crenate to serrate, gradually narrowed at the base into the petiole, at first tomentulose, particularly on the under surface, later more or less glabrate; inflorescence and base of the involucre often slightly tomentulose.

Distribution: Alaska to British Columbia and Montana.

Specimens examined:

Alaska: on gravel flood-plain of the Kuskokwim River, 19 July, 1902, *Brooks & Prindle* (U. S. Nat. Herb.).

British Columbia: Bonaparte River, 18 June, 1889, *Macoun* (U. S. Nat. Herb. 219791, in part); South Thompson River at Kamloops, 10 July, 1906, *E. Wilson 686, 672* (Mo. Bot. Gard. Herb. and Geol. Surv. Canada Herb. 81261); Lake Osoyoos, 31 May, 1905, *Macoun 69357* (Gray Herb.).

Montana: Big Fork, Flathead Co., 14 June, 1904, *W. W. Jones* (Mo. Bot. Gard. Herb.).

Washington: Fort Okanogan, U. S. Exploring Expedition, *Wilkes 971* (U. S. Nat. Herb. 48747).

71. S. multnomensis Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902; Ottawa Nat. **25**:115. 1911.

An herbaceous perennial, glabrous or slightly floccose-tomentulose in the axils of the leaves, on the margins of the petioles, and in the inflorescence; stems solitary or cespitose, erect or somewhat flexuous, 3 to 7 dm. high; lower leaves oblong-oblanceolate including the petiole 4 to 15 cm. long, .8 to 2 cm. broad, obtuse or rounded at the apex, crenate-dentate to more or less lyrately lobed with remote lobes and deep rounded sinuses, narrowed at the base into a slender petiole usually exceeding the blade; upper stem-leaves sessile and pinnatisect to much reduced entire bracts; inflorescence a ter-

minal few to many-headed corymbose cyme; heads 10 to 13 mm. high, radiate; involucre campanulate, sparingly calyculate; bracts of the involucre about 21, linear-lanceolate, 7 to 10 mm. long, usually pale green, glabrous or slightly floccose-tomentulose; ray-flowers 10 to 13, rays yellow; disk-flowers numerous, about 60; achenes glabrous.

Distribution: Mackenzie south to Saskatchewan, west to eastern Washington.

Specimens examined:

Mackenzie: Fort Smith, 4 Aug., 1901, *E. A. & A. E. Preble 172* (U. S. Nat. Herb.).

Saskatchewan: without definite locality, Palliser's British N. Am. Expl. Expedition, 1858, *E. Bourgeau* (Gray Herb.); Cypress Hills, province of Assiniboia, 24 June, 1894, *Macoun 5070* (Gray Herb. and U. S. Nat. Herb.).

Alberta: dry or rocky soil, Bow Valley, five miles west of Calgary, 14 June, 1913, *Moodie* (U. S. Nat. Herb.).

British Columbia: Kicking Horse Valley, vicinity of Field, alt. 1220 m., 20 June–25 July, 1906, *Brown 486, 487* (Phil. Acad. Nat. Sci. Herb.); Glacier, 30 July, 1901, *Williamson* (C. S. Williamson Herb.); cleared land at Howser Lake, alt. 610 m., 15 June, 1905, *Shaw 722* (U. S. Nat. Herb.); Trail, 10 June, 1902, *Macoun 64989* (Gray Herb.); Trail, 18 June, 1902, *Macoun 64992* (Gray Herb. and Mo. Bot. Gard. Herb.); rocky valley of Fraser River, above Yale, 22 July, 1880, *G. Engelmann* (Mo. Bot. Gard. Herb.).

Idaho: wet soil, Kootenai Co., alt. 900 m., July, 1900, *Leiberg* (Mo. Bot. Gard. Herb.).

Washington: Coleville Reservation, June, 1902, *Griffiths & Cotton 366* (U. S. Nat. Herb.).

Oregon: sandy flats, Cascades, 25 May, 1869, *Kellogg & Harford 537* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Multnomah Co., June, 1877, *T. J. Howell 221* (Gray Herb.), TYPE.

72. S. laetiflorus Greene, Pittonia 3:88. 1896.

S. aureus var. *borealis* Eaton, in Bot. King's Exp. 190. 1871, not Torr. & Gray.

S. cymbalarioides var. *diversilobus* Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. 32:20. 1902.

An herbaceous perennial, glabrous, or in the early stages slightly white-flocculose-tomentulose and soon glabrate; stems 2 to 5 dm. high, simple or branched from the base; lower leaves petiolate, broadly ovate, elliptic-oblong to obovate, 1 to 6.5 cm. long, .5 to 4.5 cm. broad, entire to crenate-dentate, cuneate at the base and more or less decurrent on the petiole, thick and firm in texture; petioles 1.5 to 14 cm. long; stem-leaves sublyrate or irregularly pinnate-lobed with remote lobes, the uppermost sessile, semi-amplexicaul, often much reduced; inflorescence a few to many-headed corymbose cyme; heads 8 to 10 mm. high, radiate; involucre campanulate, sparingly calyculate; bracts of the involucre (13–)21, linear-lanceolate, 5 to 8 mm. long, thickish, glabrous or at first slightly tomentulose and glabrate; ray-flowers about 13, rays pale yellow; disk-flowers numerous; achenes glabrous.

Distribution: Oregon, California, Idaho, and Nevada.

Specimens examined.

Oregon: moist meadows, Powder River Valley, alt. 1065 m., June–July, 1897, *Cusick 1617* (Gray Herb., U. S. Nat. Herb., Greene Herb., and Mo. Bot. Gard. Herb.); Otis Creek, alt. 1100 m., 19 June, 1896, *Leiberg 2324* (U. S. Nat. Herb.); near Devine ranch, alt. 1290 m., 27 June, 1896, *Leiberg 2411* (U. S. Nat. Herb.); Harney Valley, 29 May, 1885, *Th. Howell* (Gray Herb. and U. S. Nat. Herb.); near Silver Lake, alt. 1470 m., 20 Aug., 1894, *Leiberg 764* (Mo. Bot. Gard. Herb.), and *764a, 764b* (U. S. Nat. Herb.); Annie Creek, 8 Aug., 1897, *Mrs. R. M. Austin 1618* (U. S. Nat. Herb.).

California: near Boca, 26 July, 1895, *E. L. Greene* (Greene Herb.), TYPE; Gazelle, Siskiyou Co., 20 June, 1905, *Heller 8076* (U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.); Purdy, Sierra Co., 1 July, 1907, *Heller & Kennedy 8665* (U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.); Summit, *Bolander & Kellogg* (Gray Herb.); Sierraville, alt. 1525 m., *Hall & Babcock 4473* (Gray Herb.); Little Truckee River, alt. 2740 m., July, 1903,

Hall & Babcock 4526 (Gray Herb.); Sierra Nevada Mountains, coll. of 1875, *Lemmon* (U. S. Nat. Herb. 48715).

Nevada: Hunter Creek Cañon, Washoe Co., alt. 1830 m., 18 June, 1912, *Heller 10479* (U. S. Nat. Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.); Lemmon Valley, Washoe Co., alt. 1830 m., 8 July, 1913, *Kennedy 2066* (Mo. Bot. Gard. Herb.); Carson City, alt. 1525 m., 4 June, 1897, *M. E. Jones* (U. S. Nat. Herb. 359610); near Carson City, coll. of 1865, *Anderson* (Gray Herb.); Ruby Valley, alt. 1830 m., U. S. Geol. Expl. of the 40th Parallel, July, 1868, *Watson 670* (Gray Herb. and U. S. Nat. Herb.); without definite locality, coll. of 1872, *Lieut. Wheeler* (U. S. Nat. Herb. 48772).

Idaho: in patches on open slopes, Deer Creek, Owyhee Co., 1 July, 1912, *Nelson & Macbride 1850* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); moist sunny slopes, Three Creek, Owyhee Co., 1 July, 1912, *Nelson & Macbride 2247* (U. S. Nat. Herb.).

73. S. Suksdorfii Greenm. Bot. Gaz. 53:511. 1912; Piper & Beattie, Fl. Northwest Coast 389. 1915.

S. Adamsi Howell, Fl. Northwest Am. 1:379. 1900, not *S. Adamsii* Cheesem. Trans. N. Z. Inst. 28:536. 1896; Piper, Contr. U. S. Nat. Herb. 11:598. 1906.

An herbaceous perennial, slightly white-floccose-tomentulose in the leaf-axils and on the margins of the petioles near their base, otherwise glabrous; stems one to several from a rather stout rootstock, 1 to 2.5 dm. high; lower leaves petiolate, broadly ovate, 1 to 4 cm. long, 1 to 2.5 cm. broad, subtruncate to abruptly contracted to a cuneate base, crenate-dentate from base to apex, glabrous on both surfaces; petioles 1 to 5 cm. long; stem-leaves petiolate and sublyrate to sessile and more or less incised-dentate; inflorescence a few to several-headed corymbose cyme; heads 8 to 10 mm. high, radiate; ray-flowers 8 to 12, rays yellow; disk-flowers numerous; achenes glabrous.

Distribution: Washington to Nevada and California.

Specimens examined:

Washington: Mt. Adams (Paddo), alt. about 2155 m., 9 Aug., 1882, *Suksdorf 73* (Gray Herb., Geol. Surv. Canada

Herb., and Field Mus. Herb.); east of Mt. Adams (Paddo), Aug., 1892, *Henderson 2309* (Gray Herb.); Mt. Adams, alt. 1980 m., 25 July, 1899, *Flett* (U. S. Nat. Herb. 415519 in part); Indian Henry Park, Sept., 1909, *Tarleton 62* (Field Mus. Herb.).

Oregon: bases of granitic cliffs, source of the Imnaha, Wallowa Mountains, alt. 2690 m., Aug., 1906, *Cusick 3131* (U. S. Nat. Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.).

Nevada: Mt. Rose, alt. 2940 m., 29 July, 1909, *Heller 9896* (U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., Field Mus. Herb., and Mo. Bot. Gard. Herb.).

California: wet mountain slopes at Lady Bug Peak, alt. 2440 m., 12 Aug., 1900, *Leiberg 5318* (U. S. Nat. Herb.).

74. S. rubricaulis Greene, Pittonia **3**:89. 1896.

S. aureus var. *croceus* Eaton in Bot. King's Exp. 190. 1871, not Gray, Proc. Acad. Phil. **15**:68. 1863.

S. Jonesii Rydb. Bull. Torr. Bot. Club **27**:179, *pl. 5, fig. 5.* 1900.

S. cymbalarioides Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains 582. 1909, as to *S. Jonesii* in synonymy.

An herbaceous perennial, glabrous or nearly so; stems erect, 3 to 4 dm. high; lower leaves petiolate, broadly ovate to obovate, 1 to 5 cm. long, 1 to 3 cm. broad, rather coarsely dentate, abruptly cuneate at the base, glabrous on both surfaces; petioles 1 to 7 cm. long, often purplish; stem-leaves petiolate and sublyrate to sessile and pinnatifid; inflorescence a terminal few to several-headed corymbose cyme; heads 8 to 10 mm. high, radiate; involucre campanulate, sparingly calyculate; bracts of the involucre 13 to 21, linear-lanceolate, 5 to 7 mm. long, acute, glabrous, thickish, and in the later stages drying dark brown or blackish; ray-flowers 8 to 10, rays yellow; disk-flowers numerous; achenes glabrous.

Distribution: mountains of Utah, Wyoming, and Nevada.

Specimens examined:

Nevada: foothills of Clover Mountains, coll. of 1893, *E. L. Greene* (Greene Herb.), TYPE; Clover Mountains near Deeth, Elko Co., alt. 2000 m., 22 July, 1908, *Heller 9091* (Phil. Acad. Nat. Sci. Herb.).

Utah: Alta Wasatch Mountains, alt. 3350 m., 31 July, 1879, *M. E. Jones 1125* (Torrey Herb. and Field Mus. Herb.), TYPE of *S. Jonesii;* Wasatch Mountains, alt. 1525 m., May, 1869, *Watson 671* (Gray Herb.); Salt Lake City, alt. 1300 m., 15 July, 1880, *M. E. Jones 1996* (U. S. Nat. Herb.); Red Butte Cañon, Salt Lake Co., 12 July, 1906, *Garrett 1854, 1854a* (Field Mus. Herb.).

Yellowstone National Park: Electric Peak, alt. 2590 m., 26 July, 1902, *Sheldon 179* (U. S. Nat. Herb.); without definite locality, Aug., 1902, *Mearns 2671, 2719* (U. S. Nat. Herb.).

Var. **aphanactis** Greenm. var. nov.

Stem somewhat flexuous, at the base as well as the petioles more or less purplish; lower leaves rather coarsely and unequally dentate; heads about 1 cm. high, slightly nodding, discoid.

Distribution: Utah.

Specimen examined:

Utah: dry cañon, Logan, Cache Co., alt. 1525 m., 23 June, 1910, *C. P. Smith 2208* (Field Mus. Herb., photograph in Mo. Bot. Gard. Herb.), TYPE.

75. S. cymbalarioides Nutt. Trans. Am. Phil. Soc. N. S. **7**:412. 1841; Rydb. Mem. N. Y. Bot. Gard. **1**:446. 1900, in part; Bull. Torr. Bot. Club **27**:178. 1900, mainly; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902; Piper, Contr. U. S. Nat. Herb. **11**:598. 1906.

S. aureus var. *borealis* Torr. & Gray, Fl. N. Am. **2**:442. 1843, in part, i. e., *S. cymbalarioides* in synonymy; Gray, Syn. Fl. N. Am. **1**[2]:391. 1884, and ed. 2, 1886, in part.

S. aureus var. *obovatus* Eaton, in Bot. King's Exp. 190. 1871, not Torr. & Gray.

S. subenneatus Rydb. Bull. Torr. Bot. Club **27**:179, *pl. 5. fig. 6.* 1900; Fl. Colo. 397. 1906.

An herbaceous perennial, glabrous except for a white-floccose tomentum in the axils of the leaves and on the base of the petioles; stems solitary or several from a common base, 1 to 3 dm. high; lower leaves petiolate, the blade broadly ovate, obovate to somewhat spatulate, 1 to 6 cm.

long, .5 to 3 cm. broad, entire or dentate towards the apex, glabrous on both surfaces, thick and firm in texture; petioles 1 to 8 cm. long; stem-leaves petiolate or sessile, incised-serrate to entire, the uppermost much reduced; inflorescence a few to several-headed corymbose cyme; heads 8 to 10 mm. high, radiate; involucre campanulate, sparingly calyculate, glabrous or rarely slightly tomentulose at the base; bracts of the involucre linear-lanceolate, 5 to 8 mm. long, thickish, in age drying dark brown or blackish and appearing somewhat glutinous; ray-flowers 8 to 12, rays yellow; disk-flowers numerous; achenes glabrous.

Distribution: Alberta and British Columbia, south to New Mexico and Nevada.

Specimens examined.

British America: Explorations in subarctic America, coll. of 1862, *Onion, Kennicott & Hardisty* (U. S. Nat. Herb.).

Montana: Duck Lake, 23 June, 1901, *Weller* (U. S. Nat. Herb.); hills and plains, Midvale, 17 and 24 June, 1903, *Umbach 78, 154* (U. S. Nat. Herb.); Little Belt Pass, alt. 2130 m., 10 Aug., 1896, *Flodman 910* (U. S. Nat. Herb.); near Red Lodge, 28 July, 1893, *Rose 79* (U. S. Nat. Herb.); Jack Creek Cañon, 15 July, 1897, alt. 2135 m., *Rydberg & Bessey 5265* (U. S. Nat. Herb.).

Yellowstone National Park: Swan Lake Flat, 30 July, 1902, *Sheldon 266* (U. S. Nat. Herb.); in open aspen groves, Yellowstone River, near Junction Butte, 10 July, 1899, *A. & E. Nelson 5823* (U. S. Nat. Herb., Gray Herb., and Mo. Bot. Gard. Herb.).

Wyoming: mountain sides, head of Middle Fork on Powder River, Big Horn Co., 19 July, 1901, *Goodding 302* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); grassy hillside, Ten Sleep Lakes, Big Horn Co., 30 July, 1901, *Goodding 414* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); northwestern Wyoming, 4 Sept., 1893, *Rose 683* (U. S. Nat. Herb.); flats near Holm Lodge, 28 June, 1911, *Reynolds 5* (Field Mus. Herb.); river bottoms, En-

campment, alt. 2195 m., 20 June, 1901, *Tweedy 4130* (U. S. Nat. Herb.).

Colorado: Grizzly Creek, 19 July, 1896, alt. 2590 m., *Baker* (Mo. Bot. Gard. Herb.), CO-TYPE of *S. subcuneatus.*

New Mexico: Baldy, 14 Aug., 1910, *Wooton* (U. S. Nat. Herb.).

Idaho: moranic ridge, south of Petit Lake, alt. 2195–2285 m., 14 Aug., 1895, *Evermann 330* (U. S. Nat. Herb.); Beaver Cañon, 28 June, 1895, *Shear 3028* (U. S. Nat. Herb.); timbered slopes, Mackay (Bear Cañon), Custer Co., alt. 2435 m., 31 July, 1911, *Nelson & Macbride 1510* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); four miles south of Ketchum, 23 July, 1895, *Henderson 3234* (U. S. Nat. Herb.); Henry's Lake and Mt. Chauvet, alt. 3050 m., 29 July, 1897, *Rydberg & Bessey 5267* (U. S. Nat. Herb. and Kew Herb.).

Utah: Wasatch Mountains, alt. 2135 m., June, 1869, *Watson 669* (Gray Herb.); Fish Lake, alt. 3050 m., 2 Aug., 1894, *Jones 57170* (U. S. Nat. Herb. 235767); Thousand Lake Mountain, alt. 3140 m., U. S. Geol. and Geog. Survey of the Territories, 13 July, 1875, *Ward 366* (U. S. Nat. Herb. 143111 in part).

Nevada: sagebrush flats, Mountain City, alt. 1830 m., 13 Aug., 1912, *Nelson & Macbride 2201* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); meadow, vicinity of Gold Creek, 6 Aug., 1913, *Hitchcock 1054* (U. S. Nat. Herb.).

Washington: south slope of Mt. Chapa, alt. 1220 m., Aug., 1897, *Elmer 592* (Mo. Bot. Gard. Herb. and Berlin Herb.); moist slopes, head of Prince Creek, alt. 1585 m., 2 Sept., 1897, *Gorman 809* (U. S. Nat. Herb.); coniferous woods, head of Twenty-five-mile Creek, alt. 1490 m., 10 Aug., 1897, *Gorman 810* (U. S. Nat. Herb.); slopes of Mt. Stuart, alt. 1065–1830 m., 24 July, 1893, *Sandberg & Leiberg 553* (Field Mus. Herb., Greene Herb., and Mo. Bot. Gard. Herb.), CO-TYPE of *S. fraternus;* Mt. Stuart, Kittitas Co., July, 1898, *Elmer 1384* (Mo. Bot. Gard. Herb.); Yakima Region, Northern Transcontinental Survey, coll. of 1883, *Brandegee 916* (Gray Herb.).

Oregon: "Columbia woods," *Nuttall* (Phil. Acad. Nat. Sci. Herb.); "R. Mts.," *Nuttall* (Gray Herb.); river bottoms, Union Co., coll. of 1881, *Cusick 928* (Gray Herb.); Cascade Mountains, alt. 1525 m., Oregon Boundary Commission, coll. of 1860, *Lyall* (Gray Herb.).

Var. **borealis** (T. & G.) Greenm. comb. nov.

S. aureus var. *borealis* Torr. & Gray, Fl. N. Am. **2**:442. 1843, excluding *S. cymbalarioides* Nutt.; Gray, Syn. Fl. N. Am. **1**²:391. 1884, and ed. 2, 1886, in small part; Macoun, Cat. Canadian Pl. 265. 1884, in part; Porter & Coulter, Syn. Fl. Colo. 81. 1874, in part; Coulter, Manual Rocky Mountain Region 211. 1885, in part.

S. aureus Hook. Fl. Bor. Am. **1**:333. 1834, in part, not L.

S. elongatus Howell, Fl. Northwest Am. **1**:379. 1900, as to *S. aureus* var. *borealis* in synonymy, not Pursh.

Stems slender, nearly naked above; lower leaves subspatulate to oblanceolate, including the petiole 1.5 to 6 cm. long, less than 1 cm. broad; in all other characters like the species into which it passes through several intermediate forms.

Distribution: Arctic America to Wyoming and Utah.

Specimens examined:

"Arctic America": *ex Herb. Hooker* (Gray Herb.).

Alberta: Fort Chipewyan, Athabasca, 5 June, 1903, *Preble & Cary 3* (U. S. Nat. Herb.); Peace River Landing, 13 June, 1903, *Macoun 61239* (Gray Herb.).

British Columbia: Skagit Valley, alt. 1220 m., 10 July, 1905, *Macoun 69362* (Gray Herb.).

Montana: Monida, 26 June, 1900, *Blankenship* (Gray Herb.).

Wyoming: head of Big Goose Creek, Big Horn Mountains, 15–24 July, 1893, *Tweedy 65* (U. S. Nat. Herb.).

Utah: Thousand Lake Mountain, alt. 3170 m., U. S. Geol. and Geog. Survey of the Territories, 13 July, 1875, *Ward 366* (Gray Herb. and U. S. Nat. Herb. 143111 in part).

Var. **streptanthifolius** (Greene) Greenm. comb. nov.

S. streptanthifolius Greene, Erythea **3**:23. 1895; Howell, Fl. Northwest Am. **1**:375. 1900.

Lower leaves suborbicular, obovate or oblong-obovate, somewhat glaucous.

Distribution: southeastern Idaho and northwestern Wyoming.

Specimens examined:

Idaho: Beaver Cañon, 1 Aug., 1889, *E. L. Greene* (Greene Herb.), TYPE; Beaver Cañon, 29 July, 1889, *E. L. Greene* (U. S. Nat. Herb.); northwestern Wyoming, 22 Aug., 1893, *Rose 243* (U. S. Nat. Herb.).

76. S. acutidens Rydb. Bull. Torr. Bot. Club **27**:180, *pl. 5, fig. 2.* 1900; Greenm. Monogr. Senecio, I. Teil, 23. 1901, and in Engl. Bot. Jahrb. **32**:19. 1902.

S. cymbalarioides Coulter & Nelson, Manual Cent. Rocky Mountains 582. 1909, in part, as to *S. acutidens* in synonymy; Wooton & Standley, Contr. U. S. Nat. Herb. **19**:747. 1915, as to specimen cited.

An herbaceous perennial, glabrous or slightly floccose-tomentulose in the early stages and soon glabrate except in the axils of the leaves; stems 1.5 to 2.5 dm. high, erect, more or less tufted, simple or branched; lower leaves obovate to oblong-oblanceolate, including the petiole 3 to 12 cm. long, .5 to 1.5 cm. broad, dentate towards the apex, entire towards the base and gradually narrowed into the petiole, thick and firm in texture, often bluish green and somewhat glaucous; stem leaves oblanceolate and rather sparingly dentate to lance-attenuate and entire; inflorescence a terminal few to several-headed corymbose cyme; heads 8 to 10 mm. high, radiate; involucre sparingly calyculate; ray-flowers 8 to 10, rays yellow; disk-flowers numerous; achenes glabrous or rarely slightly hirtellous along the angles.

Distribution: Wyoming to New Mexico.

Specimens examined:

Wyoming: Union Pass, Wind River Range, 10 Aug., 1894, *A. Nelson 858* (N. Y. Bot. Gard. Herb., Gray Herb., U. S.

Nat. Herb., Greene Herb., and Mo. Bot. Gard Herb.), TYPE; near Fort Bridger, coll. of 1873, *Pruddon* (Gray Herb.).

Colorado: Denver, Lieut. Wheeler's Expedition, 1873, *Wolf & Rothrock 558* (Gray Herb. and U. S. Nat. Herb.); Union Creek Pass, Lieut. Wheeler's Expedition, 1873, *Wolf & Rothrock 586* (U. S. Nat. Herb. and Gray Herb.).

New Mexico: Costilla Valley, alt. 3050 m., 5 Sept., 1913, *Wooton* (U. S. Nat. Herb.).

77. S. tridenticulatus Rydb. Bull. Torr. Bot. Club **27**:175. 1900; Fl. Colo. 396. 1906.

S. compactus (Gray) Rydb. Mem. Torr. Bot. Club **5**:342. 1894, not Kirk in Trans. N. Z. Inst. **12**:395. 1880; Heller, Cat. N. Am. Pl. 146. 1898, and ed. 2, 229. 1900; Britton & Brown, Ill. Fl. **3**:480, *fig. 4045*. 1898; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902; Britton, Manual 1028. 1901, and ed. 2, 1905.

S. aureus var. *compactus* Gray, Syn. Fl. N. Am. **1**²:391. 1884, and ed. 2, 1886.

S. aureus var. *borealis* Gray, Pl. Wright., pt. 1, p.125. 1852, not Torr. & Gray.

S. oblanceolatus Rydb. Bull. Torr. Bot. Club **27**:175, *pl. 5, fig. 9*. 1900; Fl. Colo. 396. 1906; Wooton & Standley, Contr. U. S. Nat. Herb. **19**:747. 1915.

S. densus Greene, Pittonia **4**:226. 1900; Britton & Brown, Ill. Fl. **3**:546, *fig. 4631*. 1913.

S. condensatus Rydb. Fl. Colo. 396. 1906, not Greene.

S. mutabilis Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains 583. 1909, mainly, not Greene.

S. manitobensis Greenm. Ottawa Nat. **25**:117. 1911, mainly.

S. suavis Lunell, Am. Mid. Nat. **2**:125. 1911.

S. Metcalfei Greene, Contr. U. S. Nat. Herb. **16**:193. 1913; Wooton & Standley, Contr. U. S. Nat. Herb. **19**:748. 1915.

S. remifolius Wooton & Standley, Contr. U. S. Nat. Herb. **16**:194. 1913.

An herbaceous perennial, glabrous or somewhat white-floccose-tomentulose and later glabrate except at the base and in the leaf-axils; stems one to several, frequently rather

densely tufted, 1 to 3 dm. high; lower leaves oblanceolate, entire, dentate towards the apex only or even pinnatisect, gradually narrowed at the base into a slender petiole, thick and firm in texture, including the petiole 2.5 to 10 cm. long, .5 to 1 cm. broad; upper stem-leaves becoming sessile and much reduced; inflorescence a terminal few to several-headed corymbose cyme; heads 8 to 10 mm. high, radiate; involucre campanulate, sparingly calyculate; bracts of the involucre 13 to 21, linear-lanceolate, 6 to 8 mm. long, glabrous; ray-flowers 10 to 12, rays yellow; disk-flowers numerous; achenes usually hirtellous on the ribs.

Distribution: Manitoba to Texas, and west to Nebraska, Colorado, and New Mexico.

Specimens examined:

Manitoba: sand hills at Brandon and Old Wives Lakes, 22 June, 1887, *Macoun 22* (Gray Herb.); on open prairie, south of Sewell, 12 June, 1876, *Macoun* (Geol. Surv. Canada Herb. 12232); gravelly or rocky places, Flat Creek, "N. W. T.," 20 June, 1880, *Macoun 103* (Geol. Surv. Canada Herb. 14796); Stewarts Lake Mountain, 21 June, 1875, *Macoun 14777* in part (Geol. Surv. Canada Herb.); north of Carberry, 14 June, 1906, *Macoun & Herriot* (Geol. Surv. Canada Herb. and Field Mus. Herb.); without definite locality, coll. of 1898, *E. S. Thompson* (Mo. Bot. Gard. Herb.).

North Dakota: on sand hills, McHenry Co., 13 July, 1899, *Lunell 24* (Gray Herb.).

South Dakota: Hot Springs, Fall River Co., 6 June, 1893, *Schenck* (Mo. Bot. Gard. Herb.).

Nebraska: Long Pine, 14 May and 4 June, 1893, *Rutter* (U. S. Nat. Herb.); sand hills on Middle Fork, Loup River, near Thedford, Thomas Co., 15 June, 1893, *Rydberg 1311* (Gray Herb. and U. S. Nat. Herb.); in dry sandy soil, Halsey, 1 and 2 June, 1903, *Mell & Knapf* (Mo. Bot. Gard. Herb.); Hershey, 20 May, 1903, *Mell 59* (U. S. Nat. Herb.); Franklin, coll. of 1893, *Labourne* (Mo. Bot. Gard. Herb.); Loup Fork, *Hayden* (Mo. Bot. Gard. Herb.).

Oklahoma: low places on prairie, near Camp, 12 May, 1913, *Stevens 420* (Mo. Bot. Gard. Herb.); without definite locality, *Stevens 489, 511* (G. W. Stevens Herb.).

Texas: on prairies, Amarillo, 19 May, 1902, *Reverchon 2523, 3330* (Mo. Bot. Gard. Herb.); prairies near Cañon City, June, 1901, *Eggert* (Mo. Bot. Gard. Herb.); Davis Mountains, 29 April, 1902, *Tracy & Earle 336* (Gray Herb., U. S. Nat. Herb., Greene Herb., and Mo. Bot. Gard. Herb.); "mountains beyond the Limpia," Expedition from western Texas to El Paso, May–October, 1849, *Wright 403* (Gray Herb.), TYPE.

Wyoming: open woods, Laramie Hills, Albany Co., 25 June, 1903, *A. Nelson 8962* (Mo. Bot. Gard. Herb.).

Colorado: near Greeley, June, 1908, *E. L. Johnston 461, 463, 466* (Mo. Bot. Gard. Herb.); dry plains, near Evans, colls. of 1907–1909, *E. L. Johnston 423, 423a, 424, 442, 443, 537, 538, 551, 552* (Mo. Bot. Gard. Herb.); Evans, 8 June, 1912, *E. L. Johnston 804* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); in river bottoms, Fort Lupton, 19 May, 1913, *E. L. Johnston 882, 883, 875* (U. S. Nat. Herb.); Clear Creek, Hayden's U. S. Geol. Survey, 20 May, 1873, *Coulter* (Phil. Acad. Nat. Sci. Herb.), in part; Lat. 39–41°, coll. of 1864, *Parry* (U. S. Nat. Herb. 349250); Lat. 39–41°, coll. of 1862, *Hall & Harbour 333* in part (Gray Herb. and Field Mus. Herb.); Denver, May, 1881, *B. H. Smith* (Phil. Acad. Nat. Sci. Herb.); Denver, May, 1889, *Eastwood* (U. S. Nat. Herb.); Denver, 8 June, 1891, *E. C. Smith* (Mo. Bot. Gard. Herb.); Denver, *Williamson* (C. S. Williamson Herb.); dry ground, Middle Creek, July, 1892, *Beardslee 60* (U. S. Nat. Herb.); near Breckenridge, Summit Co., alt. 2950 m., *Mackenzie 112* (Mo. Bot. Gard. Herb.); pasture land, Como, alt. 3050 m., 1 Aug., 1895, *Crandall & Cowen 280* (U. S. Nat. Herb.); Leadville, *H. A. Keller* (Phil. Acad. Nat. Sci. Herb.); Leadville, 8 July, 1886, *Trelease* (Mo. Bot. Gard. Herb.); wet sandy places, along Cottonwood Creek, Buena Vista, Chaffee Co., alt. 2425–2440 m., 4 July, 1892, *Sheldon 161, 479* (U. S. Nat. Herb.); open gravel bank, near railway station,

Limon, Lincoln Co., 13 June, 1912, *Churchill* (J. R. Churchill Herb.); Colorado Springs, May, 1879, *M. E. Jones* (U. S. Nat. Herb. 223024 in part); Colorado Springs, alt. 1830 m., 8 May, 1897, *A. A. & E. G. Heller 3508* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Colorado Springs, May, 1892, *Mulford* (Mo. Bot. Gard. Herb.); Colorado Springs, 2 Aug., 1891, collector not indicated (Mo. Bot. Gard. Herb.); Pike's Peak, 10 July, 1901, *Williamson* (C. S. Williamson Herb.); plains near Westcliffe, Custer Co., 25 July, 1887, *Demetrio* (Gray Herb.); Colorado Springs, 10 May, 1882, *Allen & Brewster* (U. S. Nat. Herb. and Gray Herb.); saline soil on the plains, 12 May, 1870, *Greene* (Gray Herb.); Veta Pass, Sangre de Cristo Range, alt. 2740–3350 m., 9–16 June, 1890, *Mr. & Mrs. G. H. Hicks 9* (Gray Herb.); Veta Pass, 15 July, 1896, *Sheldon 3622* (U. S. Nat. Herb.); Pagosa Springs, 3 June, 1883, *B. H. Smith* (Phil. Acad. Nat. Sci. Herb.); southwestern Colorado, Hayden's U. S. Geol. Survey, 1875, *Brandegee* (Mo. Bot. Gard. Herb.); wet mountain valley, July, 1885, *Kettler* (Gray Herb.); in dry fields, Mancos, alt. 2135 m., 8 July, 1898, *Baker, Earle & Tracy 446* (Mo. Bot. Gard. Herb.); Rocky Mountains, coll. of 1888, *Tracy* (U. S. Nat. Herb. 48706).

Nevada: eastern Nevada, coll. of 1883, *Meehan* (Phil. Acad. Nat. Sci. Herb.).

New Mexico: dry hills, vicinity of Raton, Colfax Co., alt. 2100–2380 m., 21–22 June, 1911, *Standley 6278* (U. S. Nat. Herb.); upland slopes, Catskill, June–July, 1895, *Mrs. O. St. John 139* (Gray Herb.); plains on and near the Sierra Grande, Union Co., alt. 2100–2935 m., 19 June, 1911, *Standley 6123* (U. S. Nat. Herb.); along the river and in damp meadow, vicinity of Chama, Rio Arriba Co., alt. 2380–2850 m., 8 and 9 July, 1911, *Standley 6532, 6734* (U. S. Nat. Herb.); pass southeast of Tierra Amarilla, Rio Arriba Co., alt. 2300 m., 18 April–25 May, 1911, *Eggleston 6531, 6595* (U. S. Nat. Herb.); Hillsboro Peak, Grant Co., alt. 3100 m., 27 May, 1904, *Metcalfe 938* (U. S. Nat. Herb., Gray Herb., and Mo. Bot. Gard. Herb.), TYPE of *S. Metcalfei*; Willow

Creek, 8 Aug., 1908, *Wooton* (U. S. Nat. Herb.), TYPE of *S. remifolius*.

78. S. Wardii Greene, Pittonia **4**:116. 1900; Heller, Cat. N. Am. Pl. 231. 1900. Pl. 3, fig. 3.

A low herbaceous perennial, glabrous or slightly tomentulose in the leaf-axils; stems tufted, erect, less than 1 dm. high; lower leaves oblong-oblanceolate including the petiole 1.5 to 4 cm. long, 3 to 10 mm. broad, entire or dentate towards the obtuse or rounded apex; stem-leaves few, more or less bracteiform; inflorescence a terminal round-topped rather dense cyme; heads 6 to 8 mm. high, radiate; involucre campanulate, sparingly calyculate, glabrous or nearly so; bracts of the involucre about 13, linear-lanceolate, 4 to 5 mm. high; ray-flowers 8 to 10, rays yellow; disk-flowers numerous; achenes glabrous.

Distribution: high mountains of Utah.

Specimens examined:

Utah: Fish Lake Mountain, and Thousand Lake Mountain, alt. about 3500 m., U. S. Geol. and Geog. Survey of the Territories, 8 July, 1875, *Ward 332* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.), TYPE. This species may be looked for in herbaria under *S. aureus* var. *alpinus* under which name it was distributed.

79. S. anacletus Greene, Pittonia **4**:307. 1901; Rydb. Fl. Colo. 395. 1906; Coulter & Nelson, Manual Cent. Rocky Mountains 579. 1909. Pl. 4.

S. microdontus (Gray) Heller, Bull. Torr. Bot. Club **24**:479. 1897, not Baker; Cat. N. Am. Pl. 146. 1898, and ed. 2, 230. 1900; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902; Wooton & Standley, Contr. U. S. Nat. Herb. **19**:746. 1915.

S. Toluccanus var. *microdontus* Gray, Syn. Fl. N. Am. **1**^{2}:388. 1884, and ed. 2, 1886.

S. Wootonii Greene, Bull. Torr. Bot. Club **25**:122, *pl. 331, figs. 1, 2.* 1898.

An herbaceous perennial, glabrous throughout and usually glaucous; stems one to several from an ascending fibrous-

rooted rather stout rootstock, simple or branched, erect, 2 to 5 dm. high; lower leaves obovate to oblong-oblanceolate, including the petiole .5 to 2.5 dm. long, .5 to 4.5 cm. broad, thick and firm in texture, rounded to submucronate-acute at the apex, entire to sinuate-denticulate, gradually narrowed at the base into a slightly winged petiole; stem-leaves few, oblanceolate to lance-attenuate, sessile and entire; inflorescence terminating the stem and branches in a simple or compound corymbose cyme; heads 10 to 12 mm. high, radiate; involucre campanulate, calyculate; bracts of the involucre about 13, linear-lanceolate, 7 to 9 mm. long, acute, glabrous except at the brownish penicillate tips; ray-flowers 8 to 10, rays yellow; disk-flowers numerous; achenes striate, glabrous.

Distribution: Colorado to northern Mexico.

Specimens examined:

Colorado: pine woods below Berthoud's Pass, alt. 3200 m., 10 Aug., 1874, *G. Engelmann* (Mo. Bot. Gard. Herb.); summit of steep mountains, Estes Park, alt. 3050 m., 7 July, 1912, *Churchill* (J. R. Churchill Herb.); Tolland, alt. 2740 m., 23 July, 1913, *Overholts* (Mo. Bot. Gard. Herb.); damp places in the valley near Empire, alt. about 3050 m., 21 July, 1892, *Patterson 199* (Gray Herb.); valley near Empire, alt. 2590 m., July, 1892, *Patterson 202* (Mo. Bot. Gard. Herb.); Breckenridge, coll. of 1887, *Bereman* (Mo. Bot. Gard. Herb.); Redcliff, Eagle Co., 17 July, 1902, *Osterhout 2704* (Phil. Acad. Nat. Sci. Herb.); Leadville, 6 July, 1886, *Trelease* (Mo. Bot. Gard. Herb.); "Sawatch" Range, alt. 3350 m., Aug., 1880, *Brandegee* (Gray Herb. and Mo. Bot. Gard. Herb.); head waters of Clear Creek, etc., coll. of 1861–62, *Parry 21* (Gray Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.); Lat. 39–41°, *Hall & Harbour 326* (Gray Herb., U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.); Taylor River, alt. 2895 m., Hayden's U. S. Geol. Survey, 3 Aug., 1873, *Porter* (U. S. Nat. Herb.); meadows, South Cottonwood Gulch, Chaffee Co., alt. 3200 m., 9 July, 1892, *Sheldon 169, 188* (U. S. Nat. Herb.); Silverton,

July, 1889, *Eastwood* (U. S. Nat. Herb.); Silverton, alt. about 2895 m., 3 and 16 July, 1898, *ex Herb. Colorado State Agr. Coll. 3097, 3117* (U. S. Nat. Herb.); Pagosa Springs, 4, June, 1894, *B. H. Smith* (Phil. Acad. Nat. Sci. Herb.); Little Kate Mine, La Plata Mountains, alt. 3352 m., 16 July, 1898, *Baker, Earle & Tracy 552* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); La Plata River, 16 July, 1898, *Baker, Earle & Tracy 994* (Mo. Bot. Gard. Herb.); Rocky Mountains, coll. of 1868, *Vasey* (U. S. Nat. Herb.).

New Mexico: pass south of Tierra Amarilla, Rio Arriba Co., alt. 2320 m., 18 April–25 May, 1911, *Eggleston 6530, 6617* (U. S. Nat. Herb.); pine woods, vicinity of Brazos Cañon, Rio Arriba Co., 21 Aug., 1914, *Standley & Bollman 10676* (U. S. Nat. Herb.); Rio de la Casa, above Mora, 30 May–1 June, 1902, *Sturgis* (Gray Herb.); valley of Santa Fé Creek, at the foot of mountains, ten miles above Santa Fé, coll. of 1847, *Fendler 477 (437)* (Gray Herb., U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.); Sante Fé Cañon, nine miles east of Santa Fé, alt. 2440 m., 2 June, 1897, *A. A. & E. G. Heller 3648* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.); Hermit's Peak, San Miguel Co., Aug., 1884, *F. H. Snow* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Rio Pecos, three miles above Winsor's, alt. about 2650 m., 30 June, 1908, *Standley 4083* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); White Mountains, Lincoln Co., alt. 2130 m., 15 Aug., 1897, *Wooton* (U. S. Nat. Herb., Greene Herb., fragment in Mo. Bot. Gard. Herb.), TYPE of *S. Wootonii;* White Mountains, Lincoln Co., alt. 2255 m., 25 Aug., 1907, *Wooton & Standley 3510* (U. S. Nat. Herb.); Cloudcroft, Otero Co., alt. 2590 m., 29 May–5 June, 1902, *Viereck* (Phil. Acad. Nat. Sci. Herb.); James Cañon, Sacramento Mountains, Otero Co., 26 June, 1899, *Wooton* (U. S. Nat. Herb.); Pinos Altos Mountains, 21 May, 1880, *E. L. Greene* (Gray Herb.); Pinos Altos, 15 Aug., 1895, *Mulford 881* (Mo. Bot. Gard. Herb.).

Arizona: San Francisco Mountains, coll. of 1884, *Lemmon 3264* (Gray Herb.); San Francisco Mountains, alt. 2135–

2440 m., 22 June, 1891, *McDougal 253* (U. S. Nat. Herb.); Kendrick Peak, near Flagstaff, May–Oct., 1900, *Purpus 8001* (Mo. Bot. Gard. Herb.); near Flagstaff, alt. 1850 m., 16 Aug., 1901, *Leiberg 5859* (U. S. Nat. Herb.); Apache-Verde, east of Baker Butte, Black Mesa Forest Reserve, 1 June, 1900, *Coville 1040* (U. S. Nat. Herb.); Santa Catalina Mountains, alt. 2740 m., April, 1881, *Lemmon 190* (Gray Herb.); Rincon Mountains, alt. 2285 m., coll. of 1891, *Neally 221* (U. S. Nat. Herb.); Santa Rita Mountains, alt. 2135–2440 m., 3 May, 1881, *Pringle* (Gray Herb., U. S. Nat. Herb., and Phil. Acad. Nat. Sci. Herb.); in pine forests, Santa Rita Mountains, alt. 2285 m., 8 June, 1884, *Pringle* (Phil. Acad. Nat. Sci. Herb.); Tanner's Cañon, near Fort Huachuca, coll. of 1882, *Lemmon 2786* (Gray Herb.); Willow Spring, 10–20 June, 1890, *Dr. E. Palmer 479* (Gray Herb. and U. S. Nat. Herb.); Ramsey Cañon, Huachuca Mountains, 10 April, 1915, *Blumer 5929* (Mo. Bot. Gard. Herb.); rolling andesitic pine land, Barfoot Park, Chiricahua Mountains, alt. 2440–2500 m., 17 Sept., 1906, *Blumer 151, 1388* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.).

Chihuahua: Colonia Garcia in the Sierra Madres, alt. 2285 m., 6 June, 1899, *Townsend & Barber 14* (Gray Herb. and Mo. Bot. Gard. Herb.).

80. S. toluccanus DC. Prodr. 6:428. 1837; Schz. Bip. in Seemann, Bot. Voy. Herald 311. 1852–57; Hemsl. Biol. Cent.-Am. Bot. 2:248. 1881; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. 32:20. 1902. Pl. 5.

An herbaceous perennial; stems 2 to 10 dm. high, erect or ascending from a thick stout rootstock; lower leaves ovate to oblong-oblanceolate, including the petiole 5 to 30 cm. long, 1 to 10 cm. broad, acute or obtuse, slightly crenate to conspicuously dentate with spreading subcartilaginous teeth, narrowed at the base into a winged petiole, thick and firm in texture, glabrous on both surfaces or slightly tomentulose in the early stages and soon glabrate; stem-leaves few, sessile and semi-amplexicaul, lanceolate, dentate to entire; inflorescence terminating the stem in a

few to many-headed glabrous or somewhat pubescent corymbose cyme; heads 10 to 15 mm. high, radiate; involucre campanulate, calyculate; bracts of the involucre 13 to 21, linear-lanceolate, 7 to 9 mm. long, glabrous or nearly so; ray-flowers 10 to 12, rays yellow; disk-flowers numerous; achenes striate, glabrous.

Distribution: Mexico.

Specimens examined:

Coahuila: south of Saltillo, Feb.–Oct., 1880, *Dr. E. Palmer* (Gray Herb.).

San Luis Potosi: Valley of San Luis Potosi, Aug., 1876, *Schaffner 277* (Gray Herb. and U. S. Nat. Herb.); Valley of San Luis Potosi, alt. 1830–2440 m., *Parry & Palmer 537* (Gray Herb., U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.).

Jalisco: Nevada de Colima, alt. 3050–3650 m., 16 May, 1893, *Pringle 4374* (Gray Herb., U. S. Nat. Herb., and Mo. Bot. Gard. Herb.).

Michoacan: north slope of Mt. Patambau, alt. 2895–3350 m., 1–4 Feb., 1903, *E. W. Nelson 6598* (U. S. Nat. Herb.).

Mexico: Sierra de las Cruces, 11 Sept., 1892, *Pringle 5261* (Gray Herb.); Nevada de Toluca, 15 Oct., 1903, *Rose & Painter 7901* (Gray Herb.).

Federal District: Serrania de Ajusco, alt. 3050 m., 16 April, 1898, *Pringle 6812* (Gray Herb., U. S. Nat. Herb., Phil. Acad. Nat. Sci. Herb., and Mo. Bot. Gard. Herb.).

Southern Mexico: "cuesta de las papao pr. Angangueo", Feb., 1830, *Schiede* (Berlin Herb., Gray Herb., and U. S. Nat. Herb.); wet places on Mt. Ixtaccihuatl, alt. 2740–3050 m., Nov., 1905, *Purpus 1509* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Mt. Orizaba, 21 April, 1893, *E. W. Nelson 5* (U. S. Nat. Herb.); Mt. Orizaba, alt. 4025–4265 m., 18 March, 1894, *E. W. Nelson 281* (U. S. Nat. Herb.); wet grassy soil near timberline, Mt. Orizaba, March, 1908, *Purpus 2976* (U. S. Nat. Herb.); "Vera Cruz," *Galeotti 2183* (Kew Herb.); at the base of Jacal (Joerl), June, 1839, *Ehrenberg 1294* (Berlin Herb. and Gray Herb.); in woods near Guapi-

malpam, coll. of 1854, *Schaffner* (Gray Herb.); without definite locality, coll. of 1848–1849, *Gregg 690* in part (Mo. Bot. Gard. Herb.).

Var. **modestus** Schz. Bip. in Seemann, Bot. Voy. Herald 311. 1852–57; Hemsl. Biol. Cent.-Am. Bot. **2**:248. 1881; Greenm. Monogr. Senecio, I. Teil, 24. 1901, and in Engl. Bot. Jahrb. **32**:20. 1902.

Stems slender, 3 to 4 dm. high, nearly naked above; lower leaves oblanceolate, 3 to 14 cm. long, .5 to 1.5 cm. broad.

Distribution: northwestern Mexico.

Specimens examined:

Northwest Mexico: Sierra Madre, *Seemann* (Kew Herb. and Gray Herb.).

Chihuahua: Mound Valley, south of Pacheco, 12 June, 1891, *Hartman 690* (Gray Herb. and Mo. Bot. Gard. Herb.).

(To be continued.)

Explanation of Plate

PLATE 3

Fig. 1. *Senecio Rosei* Greenm.
Mexico

From the type specimen, Rose No. 2157, in the Gray Herbarium of Harvard University.

Fig. 2. *Senecio Wardii* Greene
Utah

From a co-type specimen, Ward No. 332, in the Gray Herbarium of Harvard University.

Fig. 3. *Senecio hesperius* Greene
Oregon

From Howell's No. 160 in the Gray Herbarium of Harvard University.

GREENMAN—MONOGRAPH OF SENECIO

Explanation of Plate

PLATE 4

Senecio anacletus Greene
United States

From Heller's No. 3648 in the Herbarium of the Missouri Botanical Garden.

GREENMAN—MONOGRAPH OF SENECIO

Explanation of Plate

PLATE 5

Senecio toluccanus DC.

Mexico

From Pringle's No. 6812 in the Gray Herbarium of Harvard University.

GREENMAN—MONOGRAPH OF SENECIO

NEW OR INTERESTING SPECIES OF GILL FUNGI FROM MISSOURI

L. O. OVERHOLTS

Formerly Rufus J. Lackland Fellow in the Henry Shaw School of Botany of Washington University

The following collections of gill fungi made by the writer in the vicinity of St. Louis, Missouri, within the past two years are believed to be undescribed.

Claudopus subnidulans Overholts, n. sp.

Pileus sessile, reniform or dimidiate in outline, convex, 0.5–2 cm. broad, bright tawny orange, fibrillose-tomentose, dry; margin inrolled, even or very slightly striate; flesh thin, white; odor and taste none; gills radiating outward from the point of attachment of the pileus, medium distant, rather broad (3–5 mm.), salmon-colored or dull orange; stem none, the pileus attached by a white tomentose base; spores salmon-colored, globose, smooth, 5–7μ broad; cystidia none.

On rotten logs in damp woods. Jefferson Barracks, near St. Louis, Missouri, October 25, 1913.

Type collection in Herb. Overholts No. 1460, and specimens from this collection are deposited in the herbarium of the Missouri Botanical Garden.

The species resembles *C. nidulans,* but differs in the constantly smaller size and the exactly globose spores.

Panaeolus reticulatus Overholts, n. sp. Plate 6, fig. 1.

Pileus hemispheric then expanded, sometimes somewhat umbonate, 3.5–6 cm. broad, between drab and light brownish umber when young, usually smoky brown or blackish with age, dry, everywhere pitted or when older appearing fibrous-recticulate; the margin even, at first incurved then wavy; flesh thin, watery, pallid; taste and odor not characteristic; gills broadly attached but sometimes sinuate, often separating with age, spotted, or in age uniformly black, rather close,

unequal, 4–7 mm. broad, the edge whitish; stem central, terete, equal or slightly tapering downward, hollow, twisted, pruinose-scabrous at the apex, somewhat shining, pale brown, cartilaginous and brittle, 4–8 cm. long, 4–8 mm. thick; veil not apparent; spores elliptic or broadly elliptic, nearly black, 8–10×5.5–6.5μ; cystidia none.

Cespitose or gregarious on earth in flower beds in the Missouri Botanical Garden, May 31, 1915; also at the same place, June 17, 1915.

Type collection in Herb. Overholts No. 2795, and specimens from this collection are deposited in the herbaria of the New York Botanical Garden and the Missouri Botanical Garden.

The species is in every way distinct from *P. retirugis* Fries and *P. alveolatus* Peck. The pileus when very young is pitted only in the center, but mature plants are pitted all over and at times appear reticulate. When dried the pileus is smooth or nearly so.

Panaeolus rufus Overholts, n. sp. Plate 6, fig. 2.

Pileus convex to nearly plane, sometimes broadly umbonate, 2–5 cm. broad, varying in color from tan to light brown or chestnut, darkest at the center, dry, glabrous, often becoming cracked and areolate except at the center; margin even, extending slightly beyond the lamellae; flesh thin, white; odor none; taste farinaceous; gills adnate or adnexed, medium close or slightly distant, spotted, becoming blackish brown, whitish on the edge; stem central, terete, pruinose, striate, light-colored above, becoming dark reddish brown below, white tomentose at the base, firm, cartilaginous, hollow, 5–10 cm. long, 2.5–6 mm. thick; veil not apparent; spores elliptic or broadly elliptic, almost black in mass, 12–13.5×7.5–9μ; cystidia none.

Gregarious on a compost heap in the Missouri Botanical Garden, June 1, 1915.

Type collection in Herb. Overholts No. 2796, and specimens from this collection are deposited in the herbaria of the Missouri Botanical Garden and the New York Botanical Garden.

The plants are more highly colored than in any described species of *Panaeolus.*

Panaeolus variabilis Overholts, n. sp. Plate 6, figs. 3, 4.

Pileus slightly campanulate to convex or plane, young specimens indistinctly umbonate, 2–6 cm. broad, very variable, when young hygrophanous, fleshy brown mingled with gray, somewhat rugose, when mature dry and lighter or creamy white, glabrous; margin even; flesh thin, concolorous; odor none; taste slightly farinaceous; gills adnate to adnexed, at first light brown, then spotted, finally black, rather close, 3–6 mm. broad, whitish on the edge; veil none; stem central, terete, equal or nearly so, pallid to slightly flesh-color or dark brown, floccose-pruinose when young, usually striate at the apex, hollow from the first, 4–9 cm. long, 2–5 mm. thick; spores broadly elliptic or ellipsoid, black, 12–13×7–9μ; cystidia none.

Gregarious or subcespitose on earth in flower beds and among shrubbery in the Missouri Botanical Garden, May 31, 1915; also from the same place, June 17, 1915.

Type collection in Herb. Overholts No. 2794, and specimens from this collection are deposited in the herbaria of the Missouri Botanical Garden and the New York Botanical Garden. The species is a very variable one.

AN INTERESTING VARIETY OF PLUTEUS CERVINUS

In November, 1914, while collecting in the region of Pacific, Missouri, the writer found a large cluster of a species of *Pluteus* growing in the sawdust on an old sawmill site. There were about thirty individuals in the cluster, and they ranged from 11 to 16 cm. broad. The specimens were much larger than is usual in *Pluteus cervinus,* and the fibrils on the pileus were much more conspicuous than in that species. These facts, together with the cespitose habit and another character mentioned below, seemed to justify the separation of these specimens into a new species. Further study has led the writer to modify this first conclusion, and the plants are now referred to *P. cervinus.* The variations are so marked, however, that they deserve notice, the accompanying

figures showing these points. For convenience this collection will be referred to below under my herbarium number, 2316.

A microscopic examination of the hymenium of this and other collections of *P. cervinus* reveals some interesting variations in the form of the cystidia. These are more or less flask-shaped structures and hyaline. The accompanying figures show the variations. In all collections examined (except the one referred to above) some of the cystidia have peculiar thorn-like projections more or less abundant. Figure *A* is from my herbarium, No. 2809, and in most collections it is probably the most typical form present. Figures *B*, *C*, and *D* are from my herbarium, No. 1624, and the thorny type

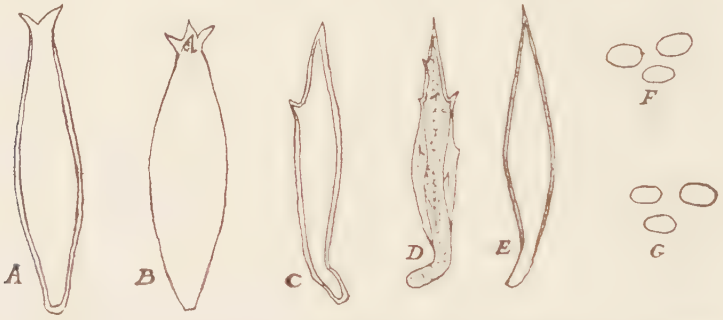


Fig. 1. Various types of cystidia found in hymenium of *Pluteus cervinus: A*, from herbarium No. 2809; *B*, *C*, and *D*, from herbarium No. 1624, the thorny type *D* being most abundant; *E*, cystidium of *P. cervinus* var. *caespitosus*. (This type is also present in other collections.) *F*, spores of *P. cervinus; G*, spores of *P. cervinus* var *caespitosus*.

of cystidium was better developed in that collection than in any other one examined. These sharp projections were most often not present on the apex of the cystidium, but were scattered along the sides as thorns on a stem. In both collections cited and in all others examined there were present also a large number of entirely smooth, sharp pointed cystidia. When collection No. 2316 was examined no cystidia with thorny projections were seen. It is very doubtful whether this is a constant character on which, together with other beforementioned facts, a new species might be segregated. However, there are certainly no such cystidia present as in the other collections; but the presence in other collections of en-

tirely smooth cystidia seems to bridge over the gap in this respect, and it seems best at present to regard this latest collection as only a variety of *Pluteus cervinus.*

P. petasatus Fries, sometimes regarded as a synonym of *P. cervinus,* approaches this collection in size and is reported as growing on sawdust, but it is described as glabrous and commonly umbonate—characters that do not apply to my plants. For convenience the present collection may be designated as follows:

Pluteus cervinus var. **caespitosus** Overholts, n. var.
Plate 6, figs. 5, 6.

Pileus 11–16 cm. broad, very slightly viscid, decorated with brownish fibrils or appressed, fibrillose scales that are more prominent in the center; gills 1–1.7 cm. broad; stem 10–15 cm. long, 1.3–2.5 cm. thick; spores oblong-ellipsoid, smooth, hyaline under the microscope, salmon-colored in mass, 4–7×3–4μ; cystidia abundant, fusiform, sharp-pointed, smooth, 40–75×10–12μ.

On heap of sawdust. Densely cespitose in a cluster of about thirty plants. Pacific, Missouri, November 9, 1914.

Type collection in Herb. Overholts No. 2316, and a single specimen from the collection has been deposited in the herbarium of the Missouri Botanical Garden. The variety is edible and quite delicious.

Explanation of Plate

PLATE 6

Fig. 1. *Panaeolus reticulatus.* From photograph of type specimen in Herbarium Overholts No. 2795.

Fig. 2. *Panaeolus rufus.* From photograph of type specimen in Herbarium Overholts No. 2796.

Figs. 3 and 4. *Panaeolus variabilis.* From photographs of type specimen in Herbarium Overholts No. 2794.

Figs. 5 and 6. *Pluteus cervinus* var. *caespitosus.* From photographs of type specimen in Herbarium Overholts No. 2316.

OVERHOLTS—GILL FUNGI

Annals
of the
Missouri Botanical Garden

Vol. 3. APRIL, 1916 No. 2

A NEW SENECIO FROM JAMAICA[1]

J. M. GREENMAN

Curator of the Herbarium of the Missouri Botanical Garden
Associate Professor in the Henry Shaw School of Botany of
Washington University

In the spring of 1908 Dr. N. L. Britton and Dr. Arthur Hollick discovered in the Parish of St. Ann's, Jamaica, a vine-like *Senecio* which appeared to them to be different from any species recorded in this genus. The plant was designated temporarily by Dr. Britton as "*S. Hollickii,* n. sp." and generously submitted to the writer for examination. From the limited material available at the time the author was unable to find sufficient characters to separate it satisfactorily from *S. Swartzii* DC. Additional specimens have been secured since, and further information acquired as to the habit of the two plants concerned. The writer takes pleasure in confirming Dr. Britton's view and in placing on record the following description:

Senecio Hollickii Britton, sp. nov.

Caulis lignescens scandens usque ad 6.5 m. longus cortice griseo tectis; ramis floriferis teretibus striatis brunneis glabris vel parce pubescentibus; foliis alternis petiolatis ovatis vel lanceolatis 2.5–12 cm. longis 1.5–4 cm. latis superne sensim angustatis acutis integris vel remote subdenticulatis utrinque glabris subtus pallidioribus basi acutis vel subcordatis, margine plus minusve revolutis; petiolis 1 cm. vel minus longis glabris; inflorescentiis terminalibus cymosis

[1]Issued September 30, 1916.

parce pilosulis multicapitatis; capitulis circiter 1 cm. altis heterogamis; involucris subcylindratis calyculatis; involucri squamis plerumque 8 lineari-lanceolatis 7–8.5 mm. longis acutis glabris penicillatis; floribus femineis 4 ligulatis, ligulis oblongo-ellipticis 4–5 mm. longis 2.5 mm. latis, aurantiabus; floribus disci plerumque 7; pappi setis albis; achaeniis striatis superne pilosis.

Specimens examined:

Jamaica: rocky hillside, Union Hill, near Moneague, Parish of St. Ann's, alt. 450 m., 6–7 April, 1908, *Britton & Hollick 2729* (N. Y. Bot. Gard. Herb., photograph and fragment in Mo. Bot. Gard. Herb.), TYPE; Pramble, near Claremont, alt. 520 m., 22 Jan., 1898, *Fawcett & Harris 7032* (N. Y. Bot. Gard. Herb.); Soho, St. Ann, alt. 425 m., 11 May, 1915, *Harris 11983* (N. Y. Bot. Gard. Herb.).

The species here described, namely *S. Hollickii,* differs from *S. Swartzii* to which it is perhaps most closely related in inflorescence, involucre and floral characters, in being a vine instead of a shrub or tree, in having ovate or lanceolate instead of oblong or obovate leaves, in having a more conspicuous venation with the lateral nerves less divaricately spreading and thus forming a more acute angle with the midrib, in having shorter petioles, and finally in having pubescent instead of glabrous achenes. Mr. William Harris states, with reference to his No. 11983 from Soho, St. Ann, that it is a plant "climbing over shrubs and trees to a height of twenty feet."

THE THELEPHORACEAE OF NORTH AMERICA VI[1]

Hypochnus

EDWARD ANGUS BURT

Mycologist and Librarian to the Missouri Botanical Garden
Associate Professor in the Henry Shaw School of Botany of Washington University

HYPOCHNUS

Hypochnus Fries emend. Karsten, Rev. Myc. 3[9]:23. 1881; Finska Vetenskaps-Soc. Bidrag Natur och Folk **37**:162. 1882; Finl. Basidsv. 438. 1889; Fries, Obs. Myc. **2**:278. 1818 and 1824, (in part); Syst. Myc. **3**:289. 1829, (in part); Gen. Hym. 16. 1836, (in part); Epicr. 569. 1838, (in part); Sacc. Syll. Fung. **6**:653. 1888, (in part); R. Fries, R. Sci. Soc. Gothoburgens Actis IV. **3**:37. 1900. — *Hypochnus* as a subgenus of *Corticium* Fries, Hym. Eur. 659. 1874, (in part). — *Tomentella* Persoon ex Patouillard,[2] Hym. Eur. 154. 1887; Schroeter,[2] Krypt.-Fl. Schlesien **3**:419. 1888; Engl. & Prantl, Nat. Pflanzenfam. (**I**:1**):117. 1898. — *Tomentellina* v. Höhnel & Litschauer, K. Akad. Wiss. Wien Sitzungsber. **115**: 1604. 1906.

Fructifications resupinate, effused, dry, coriaceous, felt-like or hypochnoid, usually composed of loosely interwoven hyphae which bear basidia sometimes in scattered clusters but more usually in a compact hymenium; hymenium even or papillose; basidia simple, bearing two or more spores, rough-walled to echinulate, distinctly colored in most species, pale-colored in a few, and hyaline in one or possibly more species.

[1]Issued September 30, 1916.

[2]Patouillard and Schroeter, in the works cited above, attributed *Tomentella* to Persoon, because he used this word in parenthesis in the names of two species in his published note-book, Obs. Myc. 2:18 and 19, 1799, as follows:

"27. Corticium (Tomentella) ferrugineum.
"28. Corticium (Tomentella) chalibeum."

This is not generic publication of Tomentella. Why Persoon used the word is not evident; he did not adopt it as a genus in his following formal taxonomic works: 'Synopsis Fungorum' published in 1801, and 'Mycologia Europaea,' in 1822. Generic publication of *Tomentella* was not made until 1887 by Patouillard six years after Karsten's emendation of Hypochnus; hence *Tomentella* is a synonym of *Hypochnus*.

Hypochnus is separated from *Thelephora*, as I have limited the latter, by strictly resupinate habit; from *Corticium* and *Peniophora* by rough-walled to echinulate spores which are usually, but not always, distinctly colored; from *Zygodesmus* of the *Hyphomycetes* by true basidia which bear two or more spores; and from *Grandinia* and *Odontia* of the *Hydnaceae* by loosely interwoven, hypochnoid structure and more or less colored, rough-walled to echinulate spores.

As here treated, the species of *Hypochnus* form a natural, compact group at the foot of *Hymenomycetes*, with simple basidia, and closely resembling *Zygodesmus* in general habit and also in form and color of spores. *Hypochnus* is so closely related to *Thelephora* and *Grandinia* that many of its species have been published in those genera, as will be seen by the synonymy of species, or occur in those genera under manuscript names in the large herbaria.

The species of *Hypochnus* are apparently humus formers, for the fructifications are found under very rotten wood and other organic matter rather than on nearly sound wood. Hence they probably follow other fungi in wood destruction.

This is the first presentation of the North American species of *Hypochnus*. It shows the geographical distribution of the genus localized in the northeastern United States and along our Atlantic coast and ranging westward across the northern United States. Not an *Hypochnus* has been found in a series of 175 numbers of *Thelephoraceae*, mostly resupinate, collected by Dr. and Mrs. Murrill in Mexico.

The sketches of microscopic details of the species in this part were made by the aid of a camera lucida from preparations of such type or authentic specimens as are referred to in the accompanying text.

The development of the present conception of *Hypochnus* is of historical interest. When first published, *Hypochnus* comprised species which I refer to *Hypochnus* and *Corticium;* then tropical lichens predominated; in his last work Fries excluded the lichens, recognized the close relationship to *Corticium* and placed both *Coniophora* and *Hypochnus* as

subgenera of *Corticium*. As several species of *Corticium* were still included in *Hypochnus*, Fries had good reason for regarding *Hypochnus* in his sense as closely related to *Corticium*. Karsten's emendation of *Hypochnus* a few years later was logical, and in sympathy with the work of Fries, for it retained this name for the greatest number of cogeneric species both originally published in the genus and retained in the final work of Fries. These species are furthermore the only species for which the generic name *Hypochnus* can be retained, for the other species of the subgenus in Fries' 'Hymenomycetes Europeae' revert to *Corticium* under modern study.

Hypochnus, as presented in Saccardo's 'Sylloge Fungorum,' is an aggregation of species of several genera and includes also the tropical lichens which Fries excluded from the genus in 1874. *Hypochnus* as given in Engler & Prantl's 'Die Natürlichen Pflanzenfamilien,' is the presentation of a purely academic scheme of Schroeter's as to how the lower *Hymenomycetes* ought to be classified to have a family *Hypochnacei*, but the fungi do not fall in with the scheme. They cannot be separated from *Corticium* and *Peniophora*. Von Höhnel and P. Sydow have pointed out [1] that *Hypochnus* in the sense of Schroeter must be abandoned as a genus and its species take their proper places in other genera. It is to be regretted that Saccardo's 'Sylloge Fungorum' and Engler & Prantl's 'Die Natürlichen Pflanzenfamilien' give a false lead with regard to *Hypochnus*, for these works are the main reliance of plant pathologists in the matter of genera.

Key to the Species

Spores distinctly colored as seen with the microscope 1
Spores so pale yellowish or hyaline as to appear hyaline or nearly so under the microscope..... 16
1. Fructification "ferruginous," i. e., Sudan-brown,* Brussels-brown, and hazel of Ridgway; spores concolorous with the fructification, but wax-yellow under the microscope..... 2

[1] Ann. Myc. 4:551. 1906. See also von Höhnel & Litschauer, Ann. Myc. 4:288. 1906.

*The technical color terms used in this work are those of Ridgway, Color Standards and Nomenclature. Washington, D. C., 1912.

1. Fructification not "ferruginous"; spores not wax-yellow under the microscope 4
1. Fructification "ferruginous"; spores wax-yellow under the microscope 3
2. Without cystidia 3
2. With cystidia consisting of non-incrusted, cylindric organs protruding from the hymenium ..... *4. H. canadensis*
3. Fructification adnate; all hyphae colored like the spores; spores echinulate ..... *1. H. ferrugineus*
3. Fructification separable from substratum; all hyphae colored like the spores; spores aculeate ..... *2. H. rubiginosus*
3. Fructification separable; hyphae dark-colored next to substratum; subhymenial hyphae colored like the spores; spores echinulate *3. H. subferrugineus*
4. Hyphae not nodose-septate, i. e., not having clamp connections 5
4. Hyphae nodose-septate, i. e., with clamp connections 6
5. Fructification ranging from drab to fuscous and Chaetura-drab, separable; spores and hyphae concolorous, dark olive-buff to buffy brown under the microscope; hyphae 4–5μ in diameter; spores aculeate or coarsely tuberculate ..... *5. H. umbrinus*
5. Fructification vinaceous-brown becoming Rood's brown, adnate; hyphae colored next to substratum, hyaline in subhymenium, 4–5μ in diameter; spores umber, aculeate, the body 5–6μ in diameter or 5–6×4–5μ ..... *21. H. subvinosus*
5. Fructification deep olive-buff to dark olive-buff, adnate; spores and hyphae concolorous; hyphae near the substratum 8–10μ, or more, in diameter; spores echinulate, the body 7–9μ in diameter ..... *12. H. isabellinus*
6. Without cystidia 7
6. With cystidia consisting of non-incrusted cylindric organs protruding from the hymenium ..... *11. H. pilosus*
7. Margin of the same color as the hymenial surface 8
7. Margin of different color from the hymenial surface 12
8. Fructification dark-colored — cinnamon-drab, umber, sepia, fuscous — and the hyphae concolorous 9
8. Fructification sepia or citrine, and the hyphae yellowish or hyaline under the microscope after treatment with KHO solution 10
8. Fructification varying in brown from Saccardo's umber and snuff-brown to cinnamon-brown; hyphae and spores concolorous with the fructification; spores echinulate, the body 6–8×5–7μ ..... *13. H. pannosus*
8. Fructification between cartridge-buff and olive-buff; hyphae and spores snuff-brown under the microscope; known from Washington only ..... *14. H. avellaneus*
8. Fructification drab or gray, and the hyphae hyaline under the microscope 11
9. Fructification with a distinct vinaceous tinge, 250–350μ thick; hyphae suberect, not rough-walled, often collapsed, rather paler than the spores under the microscope; spores aculeate or echinulate ..... *6. H. fuscus*
9. Fructification varying from Saccardo's umber to bister, rarely fuscous, 200–1200μ thick; hyphae thick-walled, not rough-walled, extending in all directions in the subiculum and loosely interwoven; spores echinulate ..... *7. H. spongiosus*
9. Resembling *H. spongiosus* but many hyphae have the wall minutely spinulose or rough; known from New Hampshire and Massachusetts ..... *8. H. spiniferus*
10. Fructification sepia, separable, 200–400μ thick; hyphae thin-walled, loosely interwoven, 2½–4μ in diameter, with some rope-like strands next to substratum; no noteworthy color change caused in sections by KHO solution ..... *9. H. granulosus*
10. Fructification citrine, adnate, the color destroyed and dissolved by KHO solution which becomes colored brownish; hyphae thin-walled, 5–6μ in diameter ..... *10. H. olivascens*
11. Fructification byssoid, drab, adnate, 60–75μ thick; hyphae short-celled, irregular in form and diameter, 4–6μ in diameter; spores grayish olive under the microscope, echinulate; known from New Hampshire ..... *15. H. sparsus*

11. Fructification felty-membranaceous, light mineral-gray, 400μ thick, two-layered; hyphae 4μ in diameter; spores deep olive-buff to hyaline under the microscope, rough-walled or aculeate with very short points; on ground in Massachusetts.....*16. H. epigaeus*
12. Fructification separable from substratum when moistened..... 13
12. Fructification adnate, fawn-color, under side and margin whitish; hyphae suberect, thin-walled, 2½–3μ in diameter, hyaline under the microscope; known from Washington.....*22. H. cervinus*
13. KHO solution causes a color change when added to sections immersed in a drop of water in making preparations..... 14
13. KHO solution causes no noteworthy color change..... 15
14. A change of color to between blue-green and sage-green is caused in the granules; fructification Chaetura-drab to fuscous, granular, the margin much paler, brownish and floccose; hyphae somewhat colored, 3–4μ in diameter.....*17. H. botryoides*
14. A change of color to sage-green is caused in the hymenium; fructification brownish olive, granular, the margin ochraceous-tawny; hyphae somewhat colored, only occasionally nodose-septate, 2½–3½μ in diameter, forming occasional rope-like strands next to substratum. .....*18. H. coriarius*
14. Original colors are destroyed and the hyphae become sage-green; fructification olive-ocher at surface, with under side and margin brownish drab; hyphae 3μ in diameter, with some rope-like hyphal strands next to substratum.....*19. H. bicolor*
15. Fructification between walnut-brown and Vandyke-brown (a "dark red") and the margin Isabella-color or melleus; hyphae colored, 5–6μ in diameter, with rope-like strands next the substratum .....*20. H. atroruber*
15. Fructification with upper side pinkish buff to Isabella-color, the under side and margin bister; hyphae, 5–7μ in diameter, run along the substratum and give off suberect, interwoven, colored branches 3½–4½μ in diameter — no rope-like strands .....*23. H. fuligineus*
15. Fructification drab-gray, the margin whitish; hyphae hyaline under the microscope .....*24. H. cinerascens*
16. Hyphae not nodose-septate, i. e., not having clamp connections 17
16. Hyphae nodose-septate..... 18
17. With cystidia; fructification pinkish buff, adnate .....*25. H. peniophoroides*
17. Without cystidia; fructification becoming warm buff, thick, and firm, like *Corticium portentosum;* hyphae 2μ in diameter, terminating in the hymenium in dichotomously branched, antler-shaped organs; basidiospores hyaline or nearly so; even spores, colored like the hyphae, abundant between the hyphae.....*26. H. thelephoroides*
17. Without cystidia; fructification pinkish buff to cinnamon-buff and avellaneous; hyphae 3½–5μ in diameter, forming some rope-like strands next to substratum; spores with a slight tinge of buff in collection on slide but hyaline under the microscope, echinulate, the body 5–6×4–4½μ. .....*27. H. zygodesmoides*
17. Without cystidia; fructification Naples-yellow to deep colonial buff; hyphae 3–4μ in diameter, not forming rope-like strands; spores concolorous but sometimes hyaline under the microscope, echinulate, the body 4–5μ in diameter .....*28. H. echinosporus*
18. Fructification between olive-buff and deep olive-buff; spores concolorous, very pale under the microscope. .....*29. H. fibrillosus*
18. Fructification honey-yellow to drab and fuscous, the margin whitish or yellowish, flaxy-fibrillose, radiating; spores white in collection on slide, minutely echinulate with short, crowded spines, body 3–5×2½–3½μ.....*30. H. fumosus*

1. Hypochnus ferrugineus Pers. ex Fries, Obs. Myc. **2**:280. 1818 and 1824; Karsten, Finska Vetenskaps-Soc. Bidrag Natur och Folk **37**:162. 1882; Finl. Basidsv. 440. 1889;

Sacc. Syll. Fung. 6:660. 1888; Bresadola, (Hym. Hung. Kmet.), I. R. Accad. Agiati Atti III. 3:114. 1897.

Corticium (Tomentella) ferrugineum Persoon, Obs. Myc. 2:18. 1799. — *Thelephora ferruginea* Persoon, Syn. Fung. 2:578. 1801; Myc. Eur. 1:141. 1822; Fries, Elenchus Fung. 1:198. 1828; Epicr. 543. 1838. — *Corticium ferrugineum* subgenus *Hypochnus* Fries, Hym. Eur. 661. 1874. — *Hypochnus ferruginosus* (Fr.) Patouillard, Tab. Anal. Fung. 17. *f. 26.* 1883. — *Tomentella ferruginea* Pers. ex Schroeter, Krypt.-Fl. Schlesien 3:419. 1888.

Illustrations: Patouillard, Tab. Anal. Fung. *f. 26.*

Fructification effused, adnate, often suborbicular, thin, dry, tomentose, hypochnoid, drying Sudan-brown; structure in section about 300μ thick, composed of loosely interwoven, even-walled hyphae 4½–5μ in diameter, nodose-septate, concolorous through the whole fructification with the hymenium; no cystidia; basidia 4-spored; spores subglobose, concolorous with the fructification, echinulate, body of spore about 7–8μ in diameter.

Fig. 1
H. ferrugineus.
Hypha, spore
×640.

Fructifications 2–4 cm. in diameter or 3–6 cm. long, about 2–3 cm. broad.

Under side decaying limbs and logs of various frondose species. Canada and New Brunswick to Georgia and westward to Michigan. July to October. Occasional.

This species is well marked by its very constant color, common to both hyphae and spores, and its occurrence in adnate, small, and very thin, hypochnoid areas of the form and dimensions given. American collections agree closely in above respects with the European specimens received from Bresadola which he has noted as surely *H. ferrugineus.*

Specimens examined:[1]

Sweden: Femsjö, *L. Romell, 225, 227.*

Austria-Hungary: Trentino, *G. Bresadola;* Tatra Magna,

[1]With regard to the citation of specimens, all except those of "Exsiccati" are in Burt Herbarium, which are cited without explicit reference to place in other herbaria. For example, the specimens cited "Sweden: Femsjö, *L. Romell, 225, 227,*" are in Burt Herbarium. The data given is that received with the

Löcse, *V. Greschik,* comm. by G. Bresadola.
New Brunswick: Campobello, *W. G. Farlow.*
New Hampshire: Chocorua, *W. G. Farlow.*
Massachusetts: Belmont Spring, *C. Bullard,* comm. by W. G. Farlow; Sharon, *A. P. D. Piguet,* comm. by W. G. Farlow.
New York: Alcove, *C. L. Shear, 1316,* in part; East Galway, *E. A. Burt,* two collections.
Georgia: Tallulah Falls, *A. B. Seymour,* comm. by W. G. Farlow (in Mo. Bot. Gard. Herb., 43911).
Wisconsin: Blue Mounds, *E. T. & S. A. Harper, 876.*

2. H. rubiginosus Bresadola, (Hym. Hung. Kmet.), I. R. Accad. Agiati Atti III. **3**:114. 1897.

Zygodesmus rubiginosus Peck, N. Y. State Mus. Rept. **30**:58. 1879. — *Tomentella rubiginosa* (Bres.) R. Maire, Ann. Myc. **4**:335. 1906.

Type: in Bresadola Herb.; probably a portion in Burt Herb.

Fructifications effused, membranaceous, somewhat separable from the substratum, dry, tomentose, drying Brussels-brown; hymenium even or granular; structure in section about 200–300μ thick, with all the hyphae bright-colored and giving their color to the fructification, about 3μ in diameter, nodose-septate, thin-walled, lax, loosely interwoven towards the hymenium, longitudinally arranged next to the substratum, and occasionally consolidated there in rope-like, branching strands up to 15μ in diameter; no cystidia; spores concolorous with the fructification or more intensely colored, subglobose-angular, aculeate, body about 6–7μ in diameter, or 7–8$\times$6μ.

Fig. 2
H. rubiginosus. Hyphal strand, spore×640.

Fructifications about 1½–3 cm. long, 1–2 cm. broad.

On decaying leaves and decaying wood. Canada, New York, Louisiana, and British Columbia. October. Rare.

specimens and may identify duplicates in another herbarium. The location of all specimens in herbaria other than my own is designated by giving in parenthesis the name of the herbarium preceded by "in." For example, the specimen cited "Georgia: Tallulah Falls, *A. B. Seymour,* comm. by W. G. Farlow (in Mo. Bot. Gard. Herb., 43911)," is in Missouri Botanical Garden Herbarium, but not in Burt Herbarium.

H. rubiginosus is very similar in color throughout to *H. ferrugineus* but differs in being membranaceous, in having spores aculeate rather than spinulose, and in having some hyphae parallel with substratum and occasionally forming rope-like strands. These strands are not mentioned by Bresadola in his description, but they are present in preparations from the specimen received from him and also in those from the few American collections referable to this species.

Specimens examined:

Hungary: on leaves of *Juniperus* and *Quercus*, Oct., 1888, *Kmet,* comm. by G. Bresadola, apparently part of type.

Canada: Lower St. Lawrence Valley, *J. Macoun, 77.*

New York: Greenbush, *C. H. Peck*, type of *Zygodesmus rubiginosus* (in Coll. N. Y. State); Alcove, *C. L. Shear, 1329;* Syracuse, *L. M. Underwood, 36, 41* (both in Coll. N. Y. State).

Louisiana: St. Martinville, *A. B. Langlois, ct.*

British Columbia: Sidney, *J. Macoun, 80,* in part (in Mo. Bot. Gard. Herb., 8935).

3. H. subferrugineus Burt, n. sp.

Type: in Burt Herb.

Fructification effused, dry, membranaceous, separable from the substratum as a thin membrane, tomentose, drying Sudan-brown, with surface often granular in the center; structure in section 300–400μ thick, composed of (1) a few dark-colored, nodose-septate hyphae 5–6μ in diameter, running parallel with the substratum, loosely interwoven or sometimes in rope-like strands which give off (2) subereet, bright-colored, interwoven branches, concolorous with the hymenium, bearing the basidia; basidia 4-spored; spores concolorous with the hymenium, subglobose, echinulate, with spore body 7–9×6–8μ; some color is dissolved from the sections when they are treated with KHO solution.

Fig. 3
H. subferrugineus. Hypha, spores ×640.

Fructifications 2–5 cm. long, about 2–3 cm. broad.

Under side of decaying limbs and logs of both coniferous and frondose species. Canada and New England to Michigan, and in British Columbia; also in Sweden. August to October. Occasional.

This species has the same color externally as *H. ferrugineus,* from which it differs in being more compact, so that it is membranaceous and may be cautiously peeled up from the substratum. Dried specimens often have their central portion cracked and curled away from the substratum, while *H. ferrugineus* is adnate. Furthermore, *H. subferrugineus* has hyphae next to the substratum dark-colored and arranged longitudinally along the surface of the substratum, which is not the case in *H. ferrugineus.*

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 421, under the name *Zygodesmus rubiginosus.*

Sweden: Femsjö, *L. Romell, 233.*

Canada: definite locality not stated, *J. Macoun, 11;* St. Lawrence Valley, *J. Macoun, 20.*

New Hampshire: Chocorua, *W. G. Farlow, 1, 3,* a collection dated Sept., 1903, and a collection dated 1915 — the last (in Mo. Bot. Gard. Herb.).

Vermont: Middlebury, *E. A. Burt,* two collections.

New York: Sylvan Beach, Oneida Co., *H. D. House* (in N. Y. State Mus. Herb. and in Mo. Bot. Gard. Herb., 5893).

New Jersey: Newfield, *J. B. Ellis,* in Ellis, N. Am. Fungi, 421.

Michigan: Ann Arbor, *A. H. W. Povah, 4* (in Mo. Bot. Gard. Herb., 11774).

British Columbia: Sidney, *J. Macoun, 26,* in part (in Mo. Bot. Gard. Herb., 8933).

4. H. canadensis Burt, n. sp.

Type: in Burt Herb.

Fructifications small, effused, membranaceous, easily separable from the substratum, dry, tomentose, drying between Brussels-brown and hazel, the margin very thin, fibrous;

hymenium even or granular; in structure 400–500μ thick, composed (1) next to the substratum of a few dark-colored, longitudinally arranged, nodose-septate hyphae 4–4½μ in diameter, and (2) towards the hymenium of pale, thin and even-walled hyphae about 2½–3μ in diameter, suberect, very loosely interwoven, which arise as lateral branches from the dark basal hyphae and bear basidia and cystidia; cystidia septate, cylindric, obtuse, even-walled, Saccardo's umber in color under the microscope, 4½–5μ in diameter, emerging up to 80–100μ; basidia 4-spored with the spores on slender sterigmata about 6μ long; spores Saccardo's umber under the microscope, globose, tuberculate, spore body 6–7μ in diameter.

Fig. 4 H. canadensis. Cystidium, spore ×640.

Fructification usually 1–2 cm. long, ½–1 cm. broad, one specimen 4 cm. long.

On wood and bark of conifers decaying on the forest floor. Canada and New Hampshire to Idaho and British Columbia. August to November.

H. canadensis is a little darker in color than *H. ferrugineus* and is smaller and less conspicuous in the few collections which have been made. It differs from our other rust-colored species of *Hypochnus* in having cystidia. It is related to the European **Hypochnus ferruginosus** (v. Höhn. & Litsch.) Burt, n. comb., = *Tomentellina ferruginosa* v. Höhn. & Litsch, by the colored, cylindric cystidia, but the cystidia of our species are shorter and its hyphae finer, darker, and nodose-septate next to the substratum.

Specimens examined:

Canada: locality not stated, *J. Macoun, 11.*

Quebec: Ironsides, *J. Macoun, 277b.*

New Hampshire: Chocorua, *W. G. Farlow, 2,* and *c1* (the latter in Mo. Bot. Gard. Herb., 44039).

Vermont: Middlebury, *E. A. Burt,* type.

Michigan: Ann Arbor, *C. H. Kauffman, 36.*

Idaho: Priest River, *J. R. Weir, 1.*

British Columbia: Kootenai Mountains, near Salmo, *J. R. Weir, 504* (in Mo. Bot. Gard. Herb.).

5. H. umbrinus (Fries) Burt, n. comb.

Thelephora umbrina Fries, Elenchus Fung. **1**:199. 1828, but not *T. umbrina* Alb. & Schw. Consp. Fung. 281. 1805. — *Corticium umbrinum* Fries, Hym. Eur. 658. 1874. — *Thelephora biennis* Fries, Hym. Eur. 636. 1874, but not *T. biennis* Fries, Syst. Myc. **1**:449. 1821. — *T. arachnoidea* Berk. & Broome, Linn. Soc. Bot. Jour. **14**:64. 1873, but not *T. arachnoidea* as understood by Bresadola, Ann. Myc. **1**:108. 1903. — *Hypochnus tristis* Karsten, Soc. pro Fauna et Flora Fennica Meddel. **9**:71. 1883; Bresadola, Ann. Myc. **1**:107. 1903. — *Hypochnopsis fuscata* Karsten, Finl. Basidsv. 443. 1889. — *Hypochnus fuscatus* Karsten in Sacc. Syll. Fung. **9**:244. 1891. — *Tomentella tristis* (Karst.) v. Höhnel & Litschauer, K. Akad. Wiss. Wien Sitzungsber. **115**:1572. 1906. — *Hypochnus sitnensis* Bresadola, I. R. Accad. Agiati Atti III. **3**:115. 1897.

Type: in Herb. Fries, and an authentic specimen from Fries in Kew Herb.

Fructification effused, soft, separable, with the hymenial surface compact and membranaceous, varying from drab to fuscous and Chaetura-drab, underneath villose; structure in section 400–600μ thick, with some hyphae running along the substratum and ascending so as to form a loosely arranged layer near the substratum and then branching repeatedly to form a compact hymenium; hyphae concolorous with the fructification, thick-walled, not nodose-septate, not rough-walled, 4–5μ in diameter; basidia with 4 sterigmata; spores concolorous, globose or subglobose, aculeate or coarsely tuberculate, 6–7μ in diameter or 6–8 $\times$ 4½–7μ; KHO solution dissolves some pigment from the sections and becomes dark-colored in their vicinity.

Fig. 5
H. umbrinus.
Section×75
Hypha×640.

Fructifications 6–10 cm. long, 3–5 cm. broad.

On rotting coniferous and frondose wood. New England to British Columbia. September to October. Common and cosmopolitan.

Hypochnus umbrinus (Fr.) is noteworthy among the dark species by its hyphae not being nodose-septate, i. e., not having clamp connections. Its tuberculate or aculeate spores and compact hymenium afford additional distinctive characters.

Thelephora umbrina Alb. & Schw. is regarded now by European botanists as a *Coniophora*, of which I have a specimen from Bresadola; what Fries understood by *T. umbrina* is exactly shown by an authentic specimen in Kew Herbarium. This specimen is a true *Hypochnus* in fine condition, dark-colored, with compact hymenium separated from the substratum by a thick layer of loosely arranged, suberect, thick-walled, colored hyphae, which do not have clamp connections. *T. biennis*, as used by Fries in 1821, is a description of the illustration in Bulliard's 'Herb. de la France' 2:286. *pl. 436. f. 2.* Fries stated that he had seen no specimens at that time. In 'Hymenomycetes Europaei,' published in 1874, he changed the description of *T. biennis* materially to adapt it to living specimens which he had seen. The resupinate specimen of this later period in Herb. Fries is not distinct from *Hypochnus umbrinus*. Authentic specimens of *H. tristis* and *Hypochnopsis fuscata* received from Karsten, and of *Hypochnus sitnensis* from Bresadola are the same species as already pointed out by Bresadola;[1] still earlier, Romell stated in letters his belief that *H. tristis* is a synonym of *H. umbrinus*. My studies lead to the same conclusion. The type specimen of *Thelephora arachnoidea* Berk. & Broome agrees closely with the Friesian specimen of *H. umbrinus*. Bresadola[2] has described hyphae of *T. arachnoidea* as "punctato-scabrae vel tunica granoso-aculeolata primitus inductae, usque ad 9μ crassae," but in my preparation of the type of *T. arachnoidea* the walls of the hyphae are even and not more than 4½μ in diameter.[3]

[1]Ann. Myc. 1:107. 1903.

[2]*Ibid.*, p. 108.

[3]In the same connection Bresadola places *Thelephora floridana* Ell. & Ev. as a synonym of *T. arachnoidea*, and he has been followed in this by von Höhnel. My preparations of the type of *T. floridana* in N. Y. Bot. Gard. Herb. show that this species is not a basidiomycete, and that its hyphae are nodose-septate.

Specimens examined:

Sweden: Smolandia, from E. Fries (in Kew Herb.); Femsjö, *L. Romell, 234, 235,* and *E. A. Burt;* Stockholm, *L. Romell, 229–232.*

Finland: Mustiala, *P. Karsten,* authentic specimen of *H. tristis;* Messuby, *P. Karsten,* authentic specimen of *Hypochnopsis fuscata.*

Hungary: *A. Kmet,* comm. by G. Bresadola, authentic specimen of *Hypochnus sitnensis.*

Ceylon: Habgalla, No. 539, Feb., 1868, the type of *Thelephora arachnoidea* Berk. & Broome (in Kew Herb.).

Canada: *J. Macoun, 64.*

Ontario: Harraby, *E. T. & S. A. Harper, 593.*

New Hampshire: Chocorua, *W. G. Farlow, 9, 13, 14, 15, 22.*

Vermont: Middlebury, *E. A. Burt.*

Massachusetts: Sharon, *A. P. D. Piguet,* comm. by W. G. Farlow.

New York: Lake Placid, *C. H. Peck;* Floodwood, *E. A. Burt.*

Wisconsin: Blue Mounds, *E. T. & S. A. Harper, 860.*

British Columbia: Kootenai Mountains, near Salmo, *J. R. Weir, 441, 487* (in Mo. Bot. Gard. Herb., 8227, and 20225 respectively).

6. **H. fuscus** Pers. ex Fries, Obs. Myc. **2**:280. 1818 and 1824; Karsten, Finska Vetenskaps-Soc. Bidrag Natur och Folk **37**:163. 1882.

Corticium fuscum Persoon, Obs. Myc. **1**:38. 1796; Fries, Hym. Eur. 651. 1874. — *Thelephora fusca* Fries, Syst. Myc. **1**:451. 1821. — *Thelephora vinosa* Persoon, Syn. Fung. **2**:578. 1801. — *Tomentella fusca* (Pers.) Schroeter, Krypt.-Fl. Schlesien **3**:419. 1888.

Type: existence of an authentic specimen unknown to me.

Fructification effused, membranaceous, separable, cinnamon-drab, darkening to Benzo-brown and Natal-brown; structure in section 200–350μ thick, with a few hyphae running along the substratum and ascending and branching or giving off suberect, loosely interwoven branches; hyphae concolorous with the fructification but rather pale under the microscope,

Fig. 6 H. fuscus. Spores ×640.

nodose-septate, 4–6μ in diameter, sometimes collapsed; basidia with 4 sterigmata; spores darker than the hyphae, subglobose, sometimes flattened on one side, the spore body 6–7μ in diameter and short-aculeate in European and occasional American specimens, but more commonly 6–8 $\times$ 6μ and echinulate in American specimens.

Fructifications 2–10 cm. long, 1–2 cm. broad.

On rotten coniferous and frondose wood of several species. Canada and New Brunswick to New Jersey and in Montana. July to October.

In the color of *H. fuscus,* there is a perceptible vinaceous component by which the species may be approximately recognized at sight. Confirmatory characters are the separable fructification and microscopical details of sections. The spores of most American specimens have slenderer and longer spines than those of European collections. *H. fuscus* is presented here as understood by Bresadola.

Specimens examined:

Sweden: Stockholm, *L. Romell, 224.*

Hungary: *A. Kmet,* comm. by G. Bresadola.

Canada: locality not given, *J. Macoun, 14;* Ottawa, *J. Macoun, 28.*

New Brunswick: Campobello, *W. G. Farlow, 4.*

Massachusetts: Magnolia, *W. G. Farlow,* two collections.

New York: Albany, *H. D. House & Jos. Rubinger* (in Mo. Bot. Gard. Herb., 8736); East Galway, *E. A. Burt;* Potsdam, *J. B. Ellis* (in Farlow Herb.).

New Jersey: Newfield, *J. B. Ellis* (in N. Y. Bot. Gard. Herb., under the name *Thelephora floridana*).

Montana: Missoula, *J. R. Weir, 400* (in Mo. Bot. Gard. Herb., 22161).

7. H. spongiosus (Schw.) Burt, n. comb.

Thelephora spongiosa Schweinitz, Naturforsch. Ges. Leipzig Schrift. **1**:109. 1822; Am. Phil. Soc. Trans. N. S. **4**:168. 1834; Fries, Elenchus Fung. **1**:193. 1828; Sacc. Syll. Fung. **6**:545. 1888. — *Hypochnus obscuratus* Karsten, Hedwigia **35**:46. 1896; Sacc. Syll. Fung. **14**:226. 1900.

Type: in Herb. Schweinitz.

Fructification effused, soft, felty-membranaceous, separable, in color varying from Saccardo's umber to bister, rarely fuscous, the margin thinning out and barely determinate; in structure 200–1200μ thick, with hyphae concolorous with the fructification, thick-walled, even, loosely interwoven, branching at a wide angle, abundantly nodose-septate, 4½–5μ in diameter or rarely 6μ; basidia with 4 sterigmata; spores concolorous, globose, or subglobose and flattened on one side, echinulate, about 6μ in diameter, or 6–9 × 6–7μ.

Fig. 7
H. spongiosus. Hypha, spore ×640.

Fructifications 4–10 cm., and more, long, 2–5 cm. broad.

On rotten wood and bark of both frondose and coniferous species. Canada to North Carolina and westward to Montana, and in Bahama Islands. July to November. Probably common.

H. spongiosus belongs in the group with *H. fuscus, H. umbrinus,* and *H. spiniferus.* The absence of a vinaceous component in its color is a useful character for separation at a glance from *H. fuscus.* If the surface of *H. spongiosus* is viewed with a lens, the component fibers are seen running in all directions, as in felt or blotting paper. *H. umbrinus* has its hyphae lacking clamp connections, i. e., not nodose-septate, and its basidia form a compact hymenium. *H. spiniferus* differs by having its hyphae spiny.

Specimens examined:

Finland: Mustiala, *P. A. Karsten,* authentic specimen of *Hypochnus obscuratus.*

Canada: Quebec, Ironsides, *J. Macoun, 255.*

New Hampshire: Chocorua, *W. G. Farlow, 14.*

Vermont: Middlebury, *E. A. Burt,* three collections; Lake Dunmore, *E. A. Burt.*

New York: Albany, *H. D. House* (in N. Y. State Mus. Herb. and in Mo. Bot. Gard. Herb., 15833).

North Carolina: *Schweinitz,* type (in Herb. Schweinitz).

Indiana: Miller, *E. T. & S. A. Harper, 758.*

Wisconsin: Lake Geneva, *E. T. & S. A. Harper, 950.*
Montana: Evaro, *J. R. Weir, 436, 438* (in Mo. Bot. Gard. Herb., 19515 and 19597 respectively).
Bahama Islands: *A. E. Wight* (in Farlow Herb.).

8. H. spiniferus Burt, n. sp.

Type: in Farlow Herb. and in Burt Herb.

Fructification effused, membranaceous, separable, tomentose, varying from sepia to fuscous; in structure about 1000μ thick, with the hyphae loosely interwoven, nodose-septate, thick-walled, concolorous with the fructification but darker near the substratum and spinulose, the paler hyphae rough-walled or even, body of largest hyphae 4–5μ in diameter, the spines about 1μ long, colored like the dark wall; basidia with 4 sterigmata; spores concolorous, globose, sometimes flattened on one side, echinulate, the body 6–8μ in diameter, or 6 × 4½–6μ.

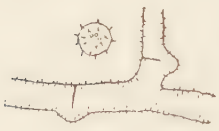


Fig. 8
H. spiniferus
Hypha, spore×640.

Fructifications about 5 cm. long, 3 cm. broad.

On rotten wood. New Hampshire and Massachusetts. August. Rare.

H. spiniferus is so similar to *H. spongiosus* in habit and coloration that it can be separated from the latter only by the distinctly spiny-walled and rough-walled hyphae of the former species. This character is as marked as in the capillitium of some *Myxomycetes*. The New Hampshire collections which I have included under *H. spiniferus* have rough-walled hyphae and no spines.

Specimens examined:
New Hampshire: Chocorua, *W. G. Farlow, 11,* and *an unnumbered specimen* collected in 1904.
Massachusetts: Magnolia, *W. G. Farlow,* type.

9. H. granulosus (Peck) Burt, n. comb.

Grandinia tabacina Cooke & Ellis, Grevillea 9:103. March, 1881, but not *Hypochnus tabacinus* Bresadola. — *Zygodesmus granulosus* Peck, Bot. Gaz. 6:277. 1881. — *Hypochnus claeodes* Bresadola, I. R. Accad. Agiati III. 3:115. 1897.

Type: in Coll. N. Y. State.

Fructification effused, thin, membranaceous, separable from the substratum, granular, sepia, the margin somewhat radiate, concolorous or nearly so; in structure 200–400μ thick, composed of very loosely interwoven, thin-walled, occasionally nodose-septate, hyphae 2½–4μ in diameter, yellowish under the microscope, forming near the substratum some rope-like mycelial strands up to 15μ in diameter; spores concolorous with the hyphae, angular-subglobose, aculeate, the body about 6μ in diameter; KHO solution produces no noteworthy color change in sections.

Fig. 9
H. granulosus. Spore, hyphal strand×640.

Fructifications 2–4 cm. long, 1–2 cm. broad.

On rotten bark and wood of frondose species. Massachusetts to New Jersey and Ohio. September to November. Rare.

H. granulosus is very closely related to *H. coriarius* and is distinguished from it by uniform color of the whole surface, while *H. coriarius* has the margin ochraceous-tawny. The lack of noteworthy color change by KHO solution is the only additional feature of difference for separating *H. granulosus* from *H. coriarius.* The specific name *tabacina* of Cooke and Ellis has priority, but is not now available because Bresadola has already used the name *Hypochnus tabacinus* for a valid species.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 421, under the name *Zygodesmus chlorochaites.*

Hungary: *A. Kmet,* authentic specimen of *H. elaeodes* from Bresadola, probably a portion of the type.

Massachusetts: Newton, *W. G. Farlow;* Mt. Tom, *H. W. Harkness,* type (in Coll. N. Y. State).

New York: Albany, *H. D. House & J. Rubinger* (in Mo. Bot. Gard. Herb., 8733); Karner, *H. D. House* (in Mo. Bot. Gard. Herb., 44731); Alcove, *C. L. Shear, 1316,* in part.

New Jersey: Newfield, *J. B. Ellis*, in Ellis, N. Am. Fungi, 421, and also the cotype of *Grandinia tabacina* (in N. Y. Bot. Gard. Herb.).

Ohio: *A. P. Morgan, 525* (in N. Y. Bot. Gard. Herb., under the manuscript name *Odontia olivacea*).

10. H. olivascens (Berk. & Curtis) Burt, n. comb.

Zygodesmus olivascens Berk. & Curtis, Grevillea 3:145. 1875.

Type: type and cotype in Kew Herb. and in Curtis Herb.

Fructification effused, thin, not separable, tomentose, citrine, yellowish citrine or buffy citrine, the margin thinning out; KHO solution dissolves some of the color upon coming in contact with the sections and becomes somewhat brownish in their vicinity; in structure 150–200μ thick, with now and then a hypha running along the substratum and sending out suberect branches which branch repeatedly, become loosely interwoven, and are somewhat clustered; basal hyphae slightly colored, nodose-septate, thin-walled, 5–6μ in diameter; basidia with 4 sterigmata; spores subglobose, concolorous with the basal hyphae, aculeate-echinulate, the body about 6μ in diameter or 5½–7½ × 5½–7μ.

Fig. 10
H. olivascens.
Spore×640.

Fructifications sometimes in little patches 1–2 cm. long, 1½–1 cm. broad, sometimes growing more or less interruptedly over areas up to 15 cm. long, 3 cm. broad.

On very rotten wood and on bark of fallen branches of both coniferous and frondose species. New Brunswick to South Carolina. September to November. Probably common.

H. olivascens is readily distinguished from other species of *Hypochnus* by its conspicuous citrine color of some kind (flavovirens of Saccardo's 'Chromotaxia') which has been retained well by the original collection for more than sixty years. From the description, *Tomentella flavovirens* v. Hohn. & Litsch. is but slightly, if at all, different from *H. olivascens*.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 422, under the name *Zygodesmus olivascens.*

New Brunswick: Campobello, *W. G. Farlow, 5.*

New Hampshire: Chocorua, *W. G. Farlow, 5, 6, 18.*

Vermont: Weybridge, *E. A. Burt.*

Massachusetts: Magnolia, *W. G. Farlow;* Hyde Park, *C. Bullard,* comm. by W. G. Farlow; Sharon, *A. P. D. Piguet* (in Farlow Herb.); Stony Brook, *G. R. Lyman, 167;* Williamstown, *W. G. Farlow, 7.*

New York: North Greenbush, *H. D. House,* two collections (in N. Y. State Mus. Herb. and in Mo. Bot. Gard. Herb., 14852, 20191); Karner, *H. D. House* (in N. Y. State Mus. Herb. and in Mo. Bot. Gard. Herb., 44719); Ithaca, *C. Thom,* Cornell Univ. Herb., 13582.

New Jersey: Newfield, *J. B. Ellis,* in Ellis, N. Am. Fungi, 422.

Pennsylvania: Kittanning, *D. R. Sumstine.*

Maryland: Takoma Park, *C. L. Shear, 1064, 1082, 1092.*

South Carolina: Society Hill, *M. A. Curtis,* cotype (in Curtis Herb., 3204).

11. H. pilosus Burt, n. sp.

Type: in Burt Herb.

Fructification effused, byssoid, membranaceous, separable from substratum, dry, tomentose, drying Sayal-brown, the margin slightly paler, thin, narrow; hymenium even in places, somewhat granular and pitted elsewhere; structure in section 200–300μ thick, composed of hyphae about 4–4½μ in diameter, branching at right angles, of the same color as the fructification, nodose-septate, rather rigid, very loosely interwoven, somewhat longitudinally interwoven next to the substratum; cystidia septate, sometimes granular incrusted, with the emergent portion colorless, thin-walled, cylindric, 5½–6μ in diameter, emerging 40–90μ, tips obtuse or clavate; spores 4 to a basidium, slightly darker than

Fig. 11
H. pilosus. Spore, cystidium×640.

the hyphae, subglobose-angular, aculeate, the spore body 7–9 × 6μ.

Fructification 8 cm. long, 2–3 cm. broad — broken off at one end.

On bark of decaying *Quercus alba,* Lake Geneva, Wisconsin, July.

This fungus suggests *Coniophora arida* and *C. puteana* by its umber color and broadly effused fructifications, but it is a true *Hypochnus,* which is readily distinguished from other species of this genus by its color, hair-like cystidia, and the spores.

Specimens examined:

Wisconsin: Lake Geneva, *E. T. & S. A. Harper, 877.*

12. H. isabellinus Fries, Obs. Myc. 2:281. *pl. 6. f. 3.* 1818 and 1824; Sacc. Syll. Fung. 6:657. 1888; Bresadola, Ann. Myc. 1:106. 1903.

Corticium isabellinum (in section *Hypochnus*) Fries, Hym. Eur. 660. 1874. — *H. argillaceus* Karsten, Soc. pro Fauna et Flora Fennica Meddel. 6:13. 1881; Sacc. Syll. Fung. 6: 661. 1888.

Type: there is a specimen from E. P. Fries in Curtis Herb.

Fructification effused, tomentose, thin, adnate, varying from deep olive-buff to dark olive-buff, the margin thinner, concolorous; in structure 60–200μ, rarely 300μ, thick, with a few hyphae 8–10μ, or more, in diameter, running along the substratum and sending out suberect, loosely interwoven branches; hyphae concolorous with the fructification, branching at right angles, thick-walled, not nodose-septate; basidia with 4 sterigmata; spores concolorous, globose, echinulate, the spore body 7–9μ in diameter.

Fig. 12
H. isabellinus.
Spore, hypha × 640.

Fructification 5–10 cm. long, 1½–3 cm. broad, and probably larger.

On rotten wood and bark of both coniferous and frondose species. Canada to Florida, in Wisconsin and in Jamaica. May to January. Probably common.

H. isabellinus is a little thinner and a little paler than *H. pannosus,* and not separable from the substratum in the collections which I have studied. It is best distinguished from the latter species by the larger hyphae of *H. isabellinus* and lack of clamp connections.

Specimens examined:

Exsiccati: Ravenel, Fungi Am., 57b, under the name *Zygodesmus pannosus;* Thümen, Myc. Univ., 2275, under the name *Zygodesmus pannosus.*

Sweden: Upsala, Halmbyboda, from E. P. Fries (in Curtis Herb.); Stockholm, *L. Romell, 219–222;* Femsjö, *L. Romell, 223,* and *E. Fries* (in Herb. Fries under the manuscript name *Hypochnus leprosus*).

Canada: Rockcliffe Park, *J. Macoun, 144;* St. Lawrence Valley, *J. Macoun, 2.*

New Hampshire: Chocorua, *W. G. Farlow,* two collections.

New Jersey: Newfield, *J. B. Ellis,* in Thümen, Myc. Univ., 2275.

Florida: Gainesville, *H. W. Ravenel,* in Ravenel, Fungi Am., 57b.

Wisconsin: New London, *E. T. & S. A. Harper, 949;* Stevens Point, *C. J. Humphrey, 1948* (in Mo. Bot. Gard. Herb., 4748).

Jamaica: Cinchona, *W. A. & Edna L. Murrill,* N. Y. Bot. Gard., Fungi of Jamaica, 630.

13. H. pannosus (Berk. & Curtis) Burt, n. comb.

Zygodesmus pannosus Berk. & Curtis, Grevillea **3**:112. 1875.

Type: cotype in Curtis Herb.

Fructification effused, byssoid-membranaceous, separable when well developed, tomentose, varying in brown from Saccardo's umber and snuff-brown to cinnamon-brown, the margin concolorous and thinning out; in structure 120–350μ thick, with an occasional hypha running along the substratum

but composed for the most part of suberect, branching, loosely interwoven, nodose-septate, thick-walled hyphae concolorous with the fructification, 4–6μ in diameter; basidia with 4 sterigmata; spores concolorous with the fructification, subglobose, sometimes flattened on one side, echinulate, the body 6–8 $\times$ 5–7μ.

Fig. 13
H. pannosus.
Spore, hypha $\times$640.

Fructification 3–6 cm. long, 1½–3 cm. broad.

On rotten wood and bark, usually of frondose species, and on the ground in woods. Canada to Louisiana; occurs in Europe also. September to December. Probably common.

H. pannosus and *H. isabellinus* are species of brown color approaching clay-color, and of cottony surface, which cannot be distinguished from each other with certainty except by microscopic characters. Well-developed fructifications of *H. pannosus* are thicker than those of *H. isabellinus* but thin fructifications of the former are frequently collected. *H. pannosus* has nodose-septate hyphae 4–6μ in diameter, while the hyphae of *H. isabellinus* are not nodose-septate and next to the substratum are 8–10μ, or more, in diameter, and occasionally 15μ in diameter. KHO solution produces no noteworthy color change. The collection from Washington, referred with doubt to this species, has the spores with body 6 $\times$ 4½μ, aculeate with scattered, very short points.

Specimens examined:

Sweden: Stockholm, *L. Romell, 225;* Femsjö, *L. Romell, 228.*
Canada: Quebec, Ironsides, *J. Macoun, 277a.*
New Hampshire: Chocorua, *W. G. Farlow, 7, 8,* and *an unnumbered specimen;* Shelburne, *W. G. Farlow, 1.*
Vermont: Middlebury, *E. A. Burt.*
Massachusetts: Magnolia, *W. G. Farlow, c;* Williamstown, *W. G. Farlow, 5.*
South Carolina: Santee Canal, *Ravenel, 1117,* cotype (in Curtis Herb., 3007).
Louisiana: St. Martinville, *A. B. Langlois, cs.*

?Washington: Bingen, on *Pinus ponderosa, W. N. Suksdorf, 860.*

14. H. avellaneus Burt, n. sp.

Type: in Burt Herb.

Fructification effused, soft, membranaceous, separable, upper side between cartridge-buff and olive-buff and under side fuscous, the margin narrow, radiate, colored like the upper surface or whitish; in structure 300–400μ thick, with the hyphae snuff-brown under the microscope, thick-walled, nodose-septate, rather compactly interwoven; basidia 4-spored; spores concolorous with the hyphae, angular-subglobose, aculeate, the body 6–7½ × 6μ.

Fig. 14
H. avellaneus. Hypha, spore× 640.

Fructification 5 cm. long, 1 cm. broad.

On wood of red fir in woods. Washington. October.

This species is marked by the pale color (nearly avellaneus of Saccardo's 'Chromotaxia') of the upper surface and margin and the fuscous subiculum.

Specimens examined:

Washington: Olympia, *C. J. Humphrey, 6305,* type.

15. H. sparsus Burt, n. sp.

Type: in Farlow Herb. and in Burt Herb.

Fructification effused, very thin, byssoid, not forming a membrane, adnate, drab, the margin of the same color, indeterminate; in structure 60–75μ thick, with the hyphae hyaline under the microscope, short-celled, irregular in form and diameter, nodose-septate; basidia 4-spored; spores grayish olive under the microscope, echinulate, 6–7 × 6μ; no noteworthy color change by KHO solution.

Fig. 15
H. sparsus. Spore, hypha ×640.

Fructification 2–3 cm. long, 1–2 cm. broad.

On bark of fallen frondose limbs. New Hampshire. August.

When better known from other collections, *H. sparsus* may prove to be *H. pannosus* very sparsely developed. At pres-

ent it appears distinct from the latter by its adnate, very thin fructification and short-celled, hyaline hyphae of irregular form and mode of branching.

Specimens examined:

New Hampshire: Madison, *W. G. Farlow, 15,* type; Chocorua, *W. G. Farlow, 16.*

16. H. epigaeus Burt, n. sp.

Type: in Farlow Herb. and in Burt Herb.

Fructification effused, soft, felty-membranaceous, tomentose, light mineral-gray, the margin thinning out and indeterminate; in structure 400μ thick, with hyphae hyaline, 4μ in diameter, thick-walled, nodose-septate, densely interwoven for 100μ next the substratum and then suberect and ascending side by side to the hymenium; basidia with 4 sterigmata; spores hyaline to deep olive-buff under the microscope, angular-globose, rough-walled or aculeate with very short points; spore body 6–7μ in diameter.

Fig. 16
H. epigaeus.
Spores×640.

Fructification about 2 cm. in diameter.

Running over ground among small mosses. Massachusetts. August.

This species is marked by its color, two-layered fructification, thick-walled and hyaline hyphae, and spores hardly more than rough-walled. *H. cinerascens* occurs on wood, is drab-gray, and has very thin-walled and delicate, loosely arranged hyphae 2–3μ in diameter, and smaller spores than *H. epigaeus*. *H. chalybeus*, as received from Bresadola, is pale at the surface only and has colored hyphae constituting the greater part of the fructification.

Specimens examined:

Massachusetts: Manchester, *W. G. Farlow, 2,* type.

17. H. botryoides (Schw.) Burt, n. comb.

Thelephora botryoides Schweinitz, Naturforsch. Ges. Leipzig Schrift. 1:109. 1822. — *T. olivacea* β *T. botryoides* Fries, Elenchus Fung. 1:198. 1828; Schweinitz, Am. Phil. Soc. Trans. N. S. 4:168. 1834; Fries, Epicr. 543. 1838. — *T.*

granosa Berk. & Curtis, Grevillea **1**:149. 1873; Sacc. Syll. Fung. **6**:546. 1888. — *Hypochnus granosus* (Berk. & Curtis) Bresadola, Ann. Myc. **1**:108. 1903. — *Zygodesmus bicolor* Cooke & Ellis, Grevillea **7**:6. 1878.

Type: in Herb. Schweinitz.

Fructification effused, membranaceous, separable, drying Chaetura-drab to fuscous, the margin much paler, brownish and floccose; hymenium distinctly and closely granular; in section 300–400μ thick, with hyphae 3–4μ in diameter, nodose-septate, somewhat colored, thin-walled, a few running along the substratum, or forming rope-like strands, and sending out suberect, loosely interwoven branches which form the greater part of the fructification; KHO solution causes an immediate change of color in the tissue of the granules to between blue-green and sage-green when added to bits of the fructification in microscopic preparations; spores concolorous with the fructification, angular-subglobose, aculeate, the spore body 5–6 $\times$ 4–5μ.

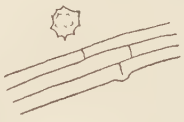


Fig. 17
H. botryoides. Spore, hyphal strand×640.

Fructifications 1–5 cm. long, 1–4 cm. broad.

On rotten wood, both coniferous and frondose. New Hampshire to South Carolina and Alabama. August to January.

The fuscous color of the central portion of the fructification, paler margin, and occurrence of granules about 4 to the mm. afford a good combination of characters for the recognition of *H. botryoides* by microscopic characters. Occasionally a fructification may vary towards Mars-brown. The blue-green color produced in the granules in microscopic preparations by adding KHO solution is a good positive character for this species, but is merely temporary.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 420, under the name *Zygodesmus bicolor* C. & E.

New Hampshire: Chocorua, *W. G. Farlow, 12,* and also a collection of Sept., 1915 (in Farlow Herb. and in Mo. Bot. Gard. Herb., 8930).

Vermont: Middlebury, *E. A. Burt,* two collections.

New York: Helderberg Mountains, *C. H. Peck* (in Coll. N. Y. State, under the name *Zygodesmus bicolor* C. & E.).
New Jersey: Belleplain, *C. L. Shear, 1253;* Newfield, *J. B. Ellis,* in Ellis, N. Am. Fungi, 420.
Pennsylvania: Bethlehem, *Schweinitz* (in Herb. Schweinitz, as the *Thelephora umbrina* of Schweinitz, Syn. N. Am. Fungi, No. 578).
Maryland: Takoma Park, *C. L. Shear, 1061, 1085.*
North Carolina: *Schweinitz,* type (in Herb. Schweinitz).
South Carolina: *M. A. Curtis, 2485, 3700,* types of *Thelephora granosa* (in Kew Herb.).
Alabama: *Peters,* type of *T. granosa* (in Kew Herb.).

18. H. coriarius (Peck) Burt, n. comb.

Grandinia coriaria Peck, Buffalo Soc. Nat. Hist. Bul. **1**:61. 1873; N. Y. State Mus. Rept. **26**:71. 1874. — *Hypochnus fulvo-cinctus* Bresadola, I. R. Accad. Agiati Atti III. **3**:116. 1897; Sacc. Syll. Fung. **14**:227. 1900.

Type: in Coll. N. Y. State.

Fructification effused, tomentose, membranaceous, separable from the substratum, under side and margin ochraceous-tawny, upper side and minute crowded granules brownish olive; in structure 200–350μ thick, composed of closely arranged, somewhat interwoven, colored, thin-walled, occasionally nodose-septate, hyphae 2½μ in diameter, forming occasional rope-like strands next to the substratum; basidia with 4 sterigmata; spores darker colored than the hyphae, subglobose-angular, aculeate, the body 5–6μ in diameter; KHO solution usually becomes dark colored next to the sections and changes the hymenial layer to sage-green.

Fig. 18
H. coriarius.
Spore, hyphal strand; ×640.

Fructifications about 3–10 cm. long, 1½–4 cm. broad.

On rotten wood, noted also on old leather and thallus of *Peltigera aphthosa.* Vermont to South Carolina and westward to Wisconsin. August to November.

This species is related to *H. botryoides* but may be distinguished from it by the more olivaceous color of the granu-

lar region and brighter and more intensely colored margin and side next to substratum, and the rope-like hyphal strands next to substratum. The sage-green color given to hymenial tissue by KHO solution is a helpful determinative character in most cases; however, I have two collections which fail to give it. *H. coriarius* occurs in Herb. Schweinitz under the name *Thelephora punicea* Alb. & Schw. The specimen is the No. 676 of Schweinitz, 'Syn. N. Am. Fungi'; it does not agree well with the original description of Albertini and Schweinitz and is not what European mycologists now understand as *Thelephora* (*Hypochnus*) *punicea.*

Specimens examined:

Hungary: *A. Kmet,* type of *H. fulvo-cinctus* (in Bresadola Herb.).

Vermont: Lake Dunmore, *W. G. Farlow* (in Farlow Herb.); Middlebury, *E. A. Burt,* three collections.

New York: Greenbush, *C. H. Peck,* type (in Coll. N. Y. State).

Pennsylvania: Kittanning, *D. R. Sumstine;* Bethlehem, *Schweinitz* (in Herb. Schweinitz, under the name *Thelephora punicea*).

South Carolina: Gourdin, *C. J. Humphrey, 3281* (in Mo. Bot. Gard. Herb., 43118).

Ohio: *C. G. Lloyd, 3882, 4199.*

Wisconsin: Blue Mounds, *E. T. & S. A. Harper, 870.*

19. H. bicolor Atkinson & Burt, n. sp.

Type: in Burt Herb. and in Cornell Univ. Herb.

Fructification effused, membranaceous, separable, dry, central portion at the surface olive-ocher, underneath brownish drab and extended laterally as a brownish drab margin 1–5 mm. broad; structure in section about 400μ thick, (1) with the hyphae next the substratum slightly colored, thin-walled, lax, long-celled, nodose-septate, 3μ in diameter, either loosely interwoven or with some hyphae consolidated together into

Fig. 19
H. bicolor.
Spore, hypha×640.

strands 6–15μ in diameter, and (2) with hyphae in the subhymenial region densely interwoven; no cystidia; basidia with spores on 4 slender sterigmata; spores olive-ocher, angular-subglobose, aculeate, the spore body 5–6 × 4½–6μ; KHO solution changes the color of both the olive-ocher and the brownish drab hyphae to sage-green, later olive-gray.

Fructification 2 cm. long, 1¼ cm. broad, with the fertile, olive-ocher portion 5–10 mm. in diameter.

On dead wood in woods. New York. August.

The single collection of this species which has been found is conspicuous by its bright olive-ocher hymenial portion surrounded by a brownish drab margin. Both of these colors are destroyed when potassium hydrate solution is brought in contact with sections of the fructification in making microscopic preparations, and the hyphae become at once sage-green, later olive-gray.

Specimens examined:

New York: Cascadilla Wood, Ithaca, *C. J. Humphrey*, comm. by G. F. Atkinson, Cornell Univ. Herb., 22571.

20. H. atroruber (Peck) Burt, n. comb.

Zygodesmus atroruber Peck, Bot. Gaz. 6:277. 1881.

Type: in Coll. N. Y. State.

Fructification effused, membranaceous, separable, tomentose, with central portion granular and between walnut-brown and Vandyke-brown, the margin often conspicuously umber or Isabella-color (melleus of Saccardo's 'Chromotaxia'); structure in section 300–500μ thick, composed of loosely interwoven thick-walled, nodose-septate hyphae 5–6μ in diameter, concolorous with the fructification and connected with a few rope-like mycelial strands 12–20μ in diameter, which run along the substratum; basidia with 4 sterigmata; spores concolorous with the darker hyphae, subglobose, often flattened on one side, echinulate, the body 6–7 × 5–6μ.

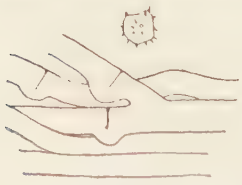


Fig. 20
H. atroruber. Spore, hyphal strand×640.

Fructifications 3–6 cm. long, 1–3 cm. broad.

On decaying wood. New Hampshire to Maryland. September to January. Probably frequent.

H. atroruber is one of our finest species of the genus. It is conspicuous by the dark red central region bordered by a melleus (in the sense of 'Chromotaxia') margin. This margin was not noticed by Peck in the original description but is present on one side of his type. Specimens of *H. atroruber* lacking the characteristic melleus margin may be distinguished from *H. rubiginosus* by the coarser, darker-colored, thicker-walled hyphae of the former species.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 1390, under the name *Zygodesmus atroruber* Pk.

New Hampshire: Chocorua, *W. G. Farlow, 10*, and collection of Sept., 1915 (in Farlow Herb. and in Mo. Bot. Gard. Herb., 8931).

Massachusetts: Mt. Tom, *H. W. Harkness,* type of *Zygodesmus atroruber* Pk. (in Coll. N. Y. State); Magnolia, *W. G. Farlow, b;* Sharon, *A. P. D. Piguet,* comm. by W. G. Farlow, 21.

New Jersey: Newfield, *J. B. Ellis,* in Ellis, N. Am. Fungi, 1390.

Maryland: Takoma Park, *C. L. Shear, 902, 1086.*

21. H. subvinosus Burt, n. sp.

Type: in Burt Herb.

Fructification effused, thin, adnate, becoming granular, tomentose, vinaceous-brown, but becoming Rood's brown in the herbarium; in structure 250–300μ thick, composed of suberect, branching, loosely interwoven, thin-walled hyphae 4–5μ in diameter, not nodose-septate, colored near the substratum and hyaline near the basidia; basidia with 4 sessile spores; spores umber, angular-subglobose, aculeate, the body 5–6μ in diameter, or 5–6 $\times$ 4–5μ; no noteworthy color change by KHO solution.

Fig. 21
H. subvinosus.
Spore, hypha×640.

Fructification 4 cm. long, 2½ cm. broad.

On bark of rotting frondose wood and on ground. New Hampshire to New Jersey. November. Rare.

The adnate habit, vinaceous-brown color of the fructifications, and the colored hyphae which are not nodose-septate, are the distinctive characters of *H. subvinosus*.

Specimens examined:

New Hampshire: Chocorua, *W. G. Farlow, 3;* Intervale, *R. Thaxter, 11* (in Farlow Herb. and in Mo. Bot. Gard. Herb., 43930).

Massachusetts: Sharon, *A. P. D. Piguet,* comm. by W. G. Farlow (in Mo. Bot. Gard. Herb., 43914).

New Jersey: Belleplain, *C. L. Shear, 1251,* type.

22. H. cervinus Burt, n. sp.

Type: in Burt Herb.

Fig. 22 H. cervinus. Hypha, spore ×640.

Fructifications in very small, interrupted, circular patches, becoming sometimes confluent and effused, byssoid, thin, not separable, fawn-color, with the under side and margin whitish; in structure 75–100μ thick, consisting of loosely interwoven, rather suberect, thin-walled hyphae 2½–3μ in diameter, nodose-septate, hyaline under the microscope; basidia with 4 sterigmata; spores slightly colored, subglobose, short aculeate, the body 5–6μ in diameter, or 6 × 5μ.

Fructifications 2–5 mm. in diameter, more or less confluent over an area 2 cm. long, 1 cm. broad.

On bark of dead *Acer macrophyllum* lying on the ground. Washington. November 1.

In the only collection which has been made, *H. cervinus* is characterized by its occurrence in very small, thin fructifications, not separable from substratum, fawn-color at the center with a whitish margin, and by having hyaline, nodose-septate hyphae. *H. cinerascens* is of different color, thicker, and separable from the substratum.

Specimens examined:

Washington: W. Klickitat County, *W. N. Suksdorf, 847,* type.

23. H. fuligineus Burt, n. sp.

Type: in Burt Herb. and in Farlow Herb.

Fructification effused, soft, felty-membranaceous, separable, upper surface pinkish buff to Isabella-color, under side and margin bister; in structure 200–1200μ thick, with hyphae bister under the microscope, thick-walled, nodose-septate, 5–7μ in diameter, a few running next to and parallel with the substratum and giving off suberect, loosely interwoven branches of the same color, 3½–4½μ in diameter; basidia with 4 sterigmata; spores bister under the microscope, globose or subglobose, echinulate, the body 6–7μ in diameter, or 6–9 × 6–7μ; no color change by KHO solution.

Fig. 23
H. fuligineus.
Hypha, spore×640.

Fructification 4–10 cm. long, 2–4 cm. broad.

On rotten frondose wood. New England and Wisconsin. August and September.

H. fuligineus is much thicker, firmer, and more spongy than *H. atroruber* and *H. cinerascens,* and differs from them further in coloration and in hyphal characters. In its thick spongy structure and microscopic details it suggests *H. spongiosus* to such a degree that I have been disposed to regard *H. fuligineus* as a subspecies of *H. spongiosus* but this seems precluded by the importance of color characters in *Hypochnus.*

Specimens examined:

New Hampshire: Chocorua, *W. G. Farlow, 4,* type.
Vermont: Middlebury, *E. A. Burt.*
Massachusetts: Magnolia, *W. G. Farlow, d,* and *an unnumbered collection* of 1903.
Wisconsin: Blue Mounds, *E. T. & S. A. Harper, 878.*

24. H. cinerascens Karsten, Soc. pro Fauna et Flora Fennica Meddel. **16**:2. 1888; Finl. Basidsv. 441. 1889; Sacc. Syll. Fung. **9**:244. 1891; Bresadola, Ann. Myc. **1**:108. 1903.

Tomentella cinerascens (Karst.) v. Höhnel & Litschauer, K. Akad. Wiss. Wien Sitzungsber. **115**:1570. 1906.

Type: authentic specimen in Burt Herb.

Fructification effused, byssoid, membranaceous, separable, drab-gray, the margin the same color or whitish; in structure 200–350μ thick, with the hyphae hyaline under the microscope, thin-walled, nodose-septate, loosely interwoven; basidia with 4 sterigmata; spores drab-gray in a spore collection, globose, echinulate, the body 4½–5½μ in diameter.

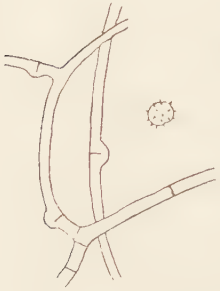


Fig. 24
H. cinerascens.
Hyphae, spore×640.

Fructification 2–3 cm. long, 1–1½ cm. broad.

On bark of *Alnus*. New Hampshire and Montana. September.

This species is distinguished from *H. epigaeus* by drab-gray color, fructification easily separable from substratum, occurrence on wood, smaller and echinulate spores, and hyphae of smaller diameter and more uniformly interwoven.

Specimens examined:
Finland: Mustiala, *P. A. Karsten.*
New Hampshire: Chocorua, *W. G. Farlow, 17.*
Montana: Missoula, *J. R. Weir, 440* (in Mo. Bot. Gard. Herb., 22144).

25. H. peniophoroides Burt, n. sp.

Type: in Burt Herb. and in N. Y. Bot. Gard. Herb.

Fructification long and widely effused, coriaceous, compact, adnate, glabrous, pinkish buff, the margin entire, determinate; in structure 300–400μ thick, stratose, composed of fine interwoven hyphae and numerous cystidia; hyphae concolorous with the fructification, 1½μ in diameter, not nodose-septate, densely interwoven, dichotomously branched, and with antler-shaped hyphal branches especially noticeable at the surface of the hymenium; cystidia very numerous in all regions of fructification, cylindric, acute, 36–

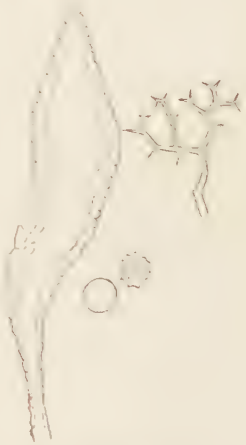


Fig. 25
H. peniophoroides.
Cystidium, antler-shaped organ, spores×640.

60 × 12μ, emerging up to 25μ; basidia with 4 sterigmata; spores globose, becoming pinkish buff and tuberculate, the body 6μ in diameter.

Fructification more than 7 cm. long, more than 4 cm. broad.

On bark of rotten frondose wood in woods. Louisiana and Jamaica. September to November.

This species is included in *Hypochnus* on account of its mature spores, whose tubercules are short and small. The immature spores are hyaline and even; hence immature specimens of this species are likely to be referred to *Peniophora*. The presence in the hymenium of dichotomously branched, antler-shaped, hyphal branches such as are present in *Corticium investiens* and *Grandinia granulosa* is a unique character which I have not observed in any species of *Peniophora* and which should make possible identification of immature specimens. In habit, *H. peniophoroides* resembles *Corticium portentosum* and *Thelephora pallescens* Schw.

Specimens examined:

Louisiana: St. Martinville, *A. B. Langlois, v.*

Jamaica: Mooretown, *F. S. Earle,* type, N. Y. Bot. Gard., Plants of Jamaica, 540.

26. H. thelephoroides (Ell. & Ev.) Burt, n. comb.

Corticium thelephoroides Ellis & Everhart, Jour. Myc. **1**:88. 1885; Sacc. Syll. Fung. **6**:630. 1888.

Type: in N. Y. Bot. Gard. Herb., and portions in Kew Herb., Farlow Herb., and Mo. Bot. Gard. Herb.

Fructification effused, adnate, thick, compact, at first pale olive-buff, becoming warm buff in the herbarium, the under side and very narrow margin Saccardo's umber; in structure 150–1200μ thick, with (1) a densely interwoven layer about 60μ thick next to substratum and (2) with a hymenial layer composed of hyphae, antler-shaped hyphal branches, and numerous imbedded, concolorous spores; hyphae thick-walled, not nodose-septate, 1½–2μ

Fig. 26
H. thelephoroides. Antler-shaped organ, spore×640.

in diameter, honey-yellow under the microscope, forming in the interior of the layer and at the surface of the hymenium numerous dichotomously branched branches with subulate tips which resemble the antlers of a stag; basidia bearing 4 spores on sterigmata; basidiospores hyaline, or very nearly so, under the microscope, rough-walled or aculeate with very short points, globose, body 5–5½μ in diameter; imbedded spores honey-yellow under the microscope, even or rarely rough, 5–6μ in diameter.

Fructification 1–4 cm. long, ½–2 cm. broad, often in lobate, connected masses.

On fir logs. Washington and British Columbia. July.

The basidia of this species show best in the recent collection 120μ thick, from which the illustration has been made. The stage of the type is much thicker apparently by growth of great numbers of the antler-like hyphal branches which conceal the basidia. This species resembles closely in habit, structure, and spore characters *Thelephora pallescens* Schw. of eastern North America, except that the spores of *T. pallescens* show by magnification with a 1½-inch objective only rarely a minutely rough wall. *H. peniophoroides* differs by having cystidia.

Specimens examined:

Washington: *Carpenter, 90*, type (in N. Y. Bot. Gard. Herb., Kew Herb., and in Mo. Bot. Gard. Herb.).

British Columbia: Vancouver, *J. Macoun, v. 178*, comm. by J. Dearness, (in Mo. Bot. Gard. Herb., 8938).

27. H. zygodesmoides (Ellis) Burt, n. comb.

Thelephora zygodesmoides Ellis, N. Am. Fungi (Exsic.), 715. 1882; Cooke, Grevillea 20:34. 1891; Sacc. Syll. Fung. 11:117. 1895.

Type: Ellis, N. Am. Fungi, 715.

Fructification effused, thin, arachnoid-membranaceous, separable from the substratum, pinkish buff to cinnamon-buff and avellaneous, the margin of the same color, narrow, byssoid; in structure 200–400 μ thick, with some rope-like strands up to 15μ in diameter next to the substratum;

hyphae pinkish buff under the microscope, thin-walled, collapsing, not nodose-septate, very loosely interwoven, 3½–5μ in diameter; basidia clavate, 28 × 5μ, with 4 short sterigmata; spores with a slight tinge of buff in collection on slide but hyaline under the microscope, ovoid, uneven to echinulate, the body 5–6 × 4–4½μ.

Fig. 27
H. zygodesmoides. Spore, hypha×640.

Fructifications 2–3 cm. long, 1–2 cm. broad.

Under side of decaying pine logs. Quebec to New Jersey. August to January. Rare.

In this species a loose subiculum is present next to the wood and bears on its surface a delicate hymenium, suggesting in habit *Corticium arachnoideum* but colored. *Hypochnus zygodesmoides* is not as bright yellow as *H. echinosporus* and has paler spores than the latter and not globose.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 715, under the name *Thelephora zygodesmoides.*

Quebec: Ironsides, *J. Macoun, 266.*

Vermont: Middlebury, *E. A. Burt.*

New Jersey: Newfield, *J. B. Ellis,* type, in Ellis, N. Am. Fungi, 715.

28. H. echinosporus (Ellis) Burt, n. comb.

Corticium echinosporum Ellis, Torr. Bot. Club Bul. **8**:64. 1881; Sacc. Syll. Fung. **6**:633. 1888; Wakefield, Brit. Myc. Soc. Trans. **5**:129. 1915.

Type: in N. Y. Bot. Gard. Herb.

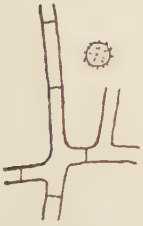


Fig. 28.
H. echinosporus. Hypha, spore ×640.

Fructification effused, membranaceous, separable, Naples-yellow to deep colonial buff, the margin concolorous, scanty, indeterminate; in structure 200μ thick, consisting of a thin, soft, hymenial membrane upon the loosely interwoven threads of the subiculum; hyphae concolorous (sometimes hyaline under the microscope), thin-walled, not nodose-septate, 3–4μ in diameter, lax, very loosely interwoven, suberect, branching towards the

outer end to form a membranous hymenium; no cystidia; basidia with 4 sterigmata; spores concolorous (sometimes hyaline under the microscope), globose, echinulate, the body 4–5μ in diameter.

Fructification 2–4 cm. long, 1–2 cm. broad.

On rotting pine wood and bark. Canada to Louisiana and in Oregon; occurs in Sweden also. August to December.

The distinguishing characters of *H. echinosporus* are its bright yellow fructifications of somewhat a straw-colored yellow, with hyphae and globose echinulate spores of the same color. Under the microscope this tint of yellow is not very intense and may be unnoticed, and regarded as hyaline. Bresadola[1] regards *Corticium echinosporum* as a synonym of *H. pellicula* Fr. (=*Corticium mollis* var *pellicula* Fr.). The specimen which Karsten has communicated to me as *Corticium pellicula* Fr. has even spores and incrusted hyphae and is a true *Corticium*. It seems best to regard *H. echinosporus* as valid until there is found an earlier name supported by an authentic specimen. It is only rarely possible to recognize resupinate species of the higher fungi from the descriptions alone of the earlier mycologists.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 608, under the name *Corticium echinosporum.*

Sweden: Stockholm, *L. Romell, 154.*

Quebec: Hull, *J. Macoun, 385.*

Ontario: Ottawa, *J. Macoun, 668.*

New York: Freeville, *G. F. Atkinson,* Bot. Dept. Cornell Univ., 3277; Ithaca, *G. F. Atkinson, 22762.*

New Jersey: Newfield, *J. B. Ellis,* in Ellis, N. Am. Fungi, 608.

Louisiana: Abita Springs, *A. B. Langlois, 2638.*

Oregon: Corvallis, *W. A. Murrill,* N. Y. Bot. Gard., Fungi of Oregon, 921, 922 (in N. Y. Bot. Gard. Herb. and in Mo. Bot. Gard. Herb., 5690 and 8937).

29. H. fibrillosus, Burt, n. sp.

Type: in Burt Herb.

[1]Ann. Myc. 1:107. 1903.

Fructification widely effused, thin, with surface a reticulate, felty web, perforate, not separable, between olive-buff and deep olive-buff; in structure 100–150μ thick, with hyphae thick-walled, nodose-septate, giving their color to the fructification but nearly hyaline under the microscope, 3–3½μ in diameter, minutely rough-walled near the substratum and sending out loosely interwoven branches which bear clusters of basidia; basidia 18 × 5μ, bearing 4 spores on short sterigmata; spores concolorous with the hyphae, angular, the body 3–3½ μ in diameter.

Fig. 29
H. fibrillosus. Spores, hypha ×640.

The specimen, 6 cm. in diameter, is a portion of a large specimen and does not show the natural margin.

On very rotten coniferous wood. Canada. September.

This species has the general habit and color of *Corticium vagum* and is well characterized by its general habit, pale color, and small angular spores.

Specimens examined:

Canada: locality not stated, *J. Macoun, 25,* Sept. 29, 1892.

30. H. fumosus Fries, Obs. Myc. **2**:279. 1818 and 1824.

Corticium fumosum Fries, Epicr. 562. 1838; Hym. Eur. 651. 1874; Sacc. Syll. Fung. **6**:613. 1888. — *Phlebia vaga* Fries, Syst. Myc. **1**:428. 1821; Elenchus Fung. **1**:155. 1828; Epicr. 527. 1838; Hym. Eur. 625. 1874; Sacc. Syll. Fung. **6**:498. 1888; Bresadola, I. R. Accad. Agiati Atti III. **3**:105. 1897.— *Corticium sulphureum* Pers. Obs. Myc. **1**:38. 1796, but not *Corticium sulphureum* Fries. — *Odontia fusca* Cooke & Ellis, Grevillea **9**:103. 1881; Sacc. Syll. Fung. **6**:509. 1888.

Fig. 30
H. fumosus. Spore×640.

Fructification effused, membranaceous, separable, with the outer surface more or less overrun with intricate, branching, anastomosing threads, then granular, honey-yellow to drab and fuscous, the margin whitish or yellowish, flaxy-fibrillose, radiating; in structure about 200μ, rarely up to 500μ, thick, with hyphae longitudinally interwoven, occasionally nodose-septate, 2½–3½μ in diameter, thin-walled, hyaline, or slightly smoky if the fructification is dark colored; no

cystidia; basidia with 4 sterigmata; spores white in collection on slide, ovoid, minutely echinulate with short crowded spines, spore body 3–5×2½–3½μ.

Fructifications 3–10 cm. long, 1½–4 cm. broad.

On rotten wood and bark of both coniferous and frondose species. Canada to North Carolina and westward to Washington, and in Jamaica. April to January. Common.

Collections of this species have been placed by recent authors in the genera *Corticium*, *Phlebia*, and *Odontia*, as an anomalous species which has no relationship to the species proper of these genera. The affinities of this fungus are with the species of *Hypochnus* by habit, dry hypochnoid structure, form of hymenial surface, and form of spore. The species is best regarded as a hyaline-spored *Hypochnus*, which is naturally connected with the dark-spored members of this genus by the pale-spored *H. echinosporus*, *H. zygodesmoides*, etc. The existence of an authentic specimen of *Hypochnus fumosus* is unknown to the writer, but this fungus is so distinguished among the species of *Thelephoraceae* that the lack of such a specimen is not serious in this case. Romell and Bresadola regard this fungus as the *H. fumosus* of Fries. My own study of the large series of Scandinavian *Thelephoraceae* received from Romell and Karsten leads me to the same conclusion.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 509; Ell. & Ev., Fungi Col., 1018, in both under the name *Odontia fusca*.

Sweden: Stockholm, *L. Romell, 96*.

Austria-Hungary: Tatra Magna, *V. Greschik*, two collections, comm. by G. Bresadola.

Canada: locality not stated, *J. Macoun, 27*; Lower St. Lawrence Valley, *J. Macoun, 23*.

New Brunswick: Campobello, *W. G. Farlow, 6*.

Ontario: Ottawa, *J. Macoun, 24*; Harraby, Lake Rosseau, *E. T. & S. A. Harper, 744*.

British Columbia: near Salmo, *J. R. Weir, 460, 528* (in Mo. Bot. Gard. Herb., 9207 and 22647 respectively).

New Hampshire: Chocorua, *W. G. Farlow, 3.*
Vermont: Middlebury, *E. A. Burt,* three collections.
Massachusetts: *W. G. Farlow* (in Farlow Herb.).
New York: Albany, *H. D. House & J. Rubinger* (in Mo. Bot. Gard. Herb., 6327); Alcove, *C. L. Shear, 1330;* Floodwood, *E. A. Burt,* four collections; Sylvan Beach, Oneida Co., *H. D. House* (in Mo. Bot. Gard. Herb., 7664); Karner, *H. D. House, 166, 168, 204* (in Mo. Bot. Gard. Herb., 44716, 44717, and 44725 respectively).
New Jersey: Belleplain, *C. L. Shear, 1252;* Newfield, *J. B. Ellis,* and also two specimens distributed in his exsiccati.
Maryland: Takoma Park, *C. L. Shear, 966.*
North Carolina: Blowing Rock, *G. F. Atkinson,* Bot. Dept. Cornell Univ., 4197.
Wisconsin: Lake Geneva, *E. T. & S. A. Harper, 898.*
Colorado: Portland Mine, Cripple Creek, *C. J. Humphrey, 7729.*
Montana: Evaro, *J. R. Weir, 423* (in Mo. Bot. Gard. Herb., 13273).
Idaho: Priest River, *J. R. Weir, 16, 22, 43.*
Washington: Bingen, *W. N. Suksdorf, 853.*
Jamaica: Monkey Hill, *W. A. Murrill,* N. Y. Bot. Gard., Fungi of Jamaica, 806.

31. H. aurantiacus (Pat.) Burt, n. comb.
Tomentella aurantiaca Patouillard, Soc. Myc. Fr. Bul. **24**:3. 1908.

Fructification obscure, aurantiacus; hyphae fuscous under the microscope, nodose-septate, 2–3μ in diameter; spores angular-globose, fuscous, 5–8μ in diameter.

On bark of trees. Guadeloupe.—Description overlooked until too late for insertion near *H. bicolor,* with which specimens should be compared.

Change of Name

Sebacina plumbea Burt, Mo. Bot. Gard. Ann. **2**.765. 1915, should be changed to *Sebacina plumbescens* Burt, for the former name is preoccupied by *Sebacina plumbea* Bres., which is not the same species.

(To be continued.)

THE OCCURRENCE IN NATURE OF CERTAIN YEAST-LIKE FUNGI WITH REFERENCE TO THEIR POSSIBLE PATHOGENICITY IN THE HIGHER ANIMALS

W. H. EMIG

Formerly Rufus J. Lackland Fellow in the Henry Shaw School of Botany of Washington University

Introduction

The biologist who studies the diseases of man and the higher animals occasionally discovers a fungus that may have importance in connection with a particular malady. At first the association of fungi in animal tissues received only a passing notice, but later research indicated that in certain diseases fungi may play an important rôle. These fungi not only affect animals as a result of their parasitic growth, but also as a toxin if consumed in large quantities on infected foods.

Up to the present time there have appeared only two general reference texts dealing with the fungous parasites of man and the higher animals. Gedoelst ('02) in 'Les champignons parasites' and Plaut ('03) in 'Die Hyphenpilze oder Eumyceten' discuss in a general way the subject of fungous parasites of animals, more particularly from a medical point of view. Both writers give historical accounts of the discoveries and investigations on this subject from the time fungi were first recognized as agents in the production of disease. These books, published more than ten years ago, are the only general treatises that have appeared abroad, and there has not appeared any general work of American origin on these fungous parasites of the higher animals. Nevertheless, for the past few years there has been active investigation in this field, and a large amount of information has been published concerning more particularly the physiological relations of parasite and host.

The purpose of the present investigation is twofold. In the first place, it seems advisable to learn from the literature on

the subject of animal pathology the relative importance of fungi as producers of diseased conditions in the higher animals. The arrangement of this material will be in taxonomic sequence with respect to the fungi. In the second place, this paper will consider the distribution in nature of the known pathogenic fungi, and also will give the results of the author's experiments to determine whether there are any organisms among the very large number of saprophytic wild yeasts that might prove pathogenic when introduced into the bodies of animals.

Quite recently Loeb, Moore, and Fleisher ('13) obtained a culture of a yeast-like organism from an infected sarcoma which had developed in the tissues of a man sixty-two years of age. After the operation was performed the tumor was removed to the laboratory, and was sterilized by searing the surface with a heated spatula. Small pieces of the tissue, removed from the interior with sterilized instruments, were placed in tubes of sterilized sugar solution; and after about twenty-four hours the culture liquid became turbid, due to the presence of a yeast-like fungus. Inoculation experiments on animals demonstrated that the organism was very pathogenic. This fungus was studied in the laboratory at the Missouri Botanical Garden by Professor George T. Moore. Its accidental occurrence in cancer and the pathogenic action on animals suggested the investigation undertaken in this paper.

Many of the so-called pathogenic fungi were carefully studied before their importance as disease-producing organisms was recognized. Other parasitic fungi were discovered only after the characteristic disease had been known for centuries, and it remained for modern methods of investigation to determine the true nature of the disease. A brief historical survey, consequently, will develop important and interesting facts bearing upon the relations of scientific research to the advancement of the study of microbiology.

The pathogenic rôle of the fungi has been much discussed. The first authors considered them as saprophytes which were developed in special circumstances, more often in a preëxisting lesion. Others, on the contrary, admit that these

moulds can establish themselves on the surface of sound mucus, develop, and extend their filaments gradually and give rise to a special disease. Weichselbaum ('78) took the view opposing Virchow, in that the mould *Aspergillus* may infect tissues that were not previously diseased.

HISTORICAL

The first report of a fungus occurring in the human body is that made in 1736 by Horn and Degener (cited by Virchow, '56) who observed a mould growth in gangrenous places on a man's foot. Heusinger in 1826 (cited by Virchow, '56), observed fungous elements in the fresh scales of a ring-worm lesion and considered this find as worthy the attention of botanists. This hint, however, remained unnoticed until the Italian, Bassi, in 1837 (cited by Plaut, '03), discovered that one type of silkworm disease was caused by a fungous parasite. Thereupon Schonlein (cited by Plaut, '03) was stimulated to investigate the infectious scalp diseases of man, with the result that in 1839 he found a hyphomycete to be the cause of the disease known as favus. This is the first incident in which a hyphomycete was known to be the cause of a human disease. At about the same time Langenbeck and Berg discovered the organism which is the cause of thrush.

An interesting observation, but of a questionable nature, is that made by Olsen in 1886 (cited by Guéguen, '05) in support of the pathogenicity of *Sterigmatocystis nigra.* Olsen reports that on removing the bandage from a large flesh wound of a man he found a black mould that seemed to have penetrated the epidermis. This fungus, upon examination under the microscope, presented all the appearances of *S. nigra.* The wound, after being washed with a sublimate solution, was redressed with an iodoform gauze and overlaid with sublimate and a layer of peat. Upon removing this bandage a week later, there was evidence of an extensive development of this same fungus. Brefeld confirmed Olsen's determination, although the spores and mycelia, when transferred to a culture solution, failed to germinate.

While the occurrence of moulds in the lungs of birds was known in 1815, it was not discovered in man until 1847. The first notice of a real pneumonomycosis caused by *Aspergillus* was made by Baum, Litzmann, and Eichstett (cited by Plaut, '03) from sections of a diseased lung taken from a woman's body shortly after death. The first scientific description of such a case is that by Virchow ('56) who, on three occasions, found in human bodies such gangrenous colonies as could be, he considered, easily differentiated, by the absence of an odor, from ordinary inflammations of the lung. The fresh lung colonies were of a hemorrhagic nature and, according to Virchow, of secondary importance. Descriptions of the parasite as found in similar instances by Fürbringer ('76) indicate that the fungus may have been a species of *Mucor*.

French authors took the view that a primary lung mycosis exists in man and may quickly change into conditions of tuberculosis; but that the lung mycosis may also be complicated with tuberculosis, whereupon the distinction becomes very difficult. Chantemesse ('91) discovered similar conditions in the men who care for pigeons, and whose lungs become diseased in consequence of their vocation. These men masticate the bird food, which consists of grain, and the young birds eat directly from the caretaker's mouth. Infection with fungous spores doubtless takes place during this feeding process. The development of the disease resembles entirely a chronic lung tuberculosis. Histologically, the lesions in birds and mammals resemble in their structure the lesions of the tubercle bacillus of Koch.

The first observation of a fungus in the ear was reported by Mayer in 1844 (cited by Plaut, '03), who found a fungous mass (possibly *Aspergillus*) in the ear of an eight-year-old girl. Pacini, in 1851, and Grove, in 1857 (cited by Plaut, '03), reported *Sterigmatocystis nigra*, and Cramer, in 1859 (cited by Plaut, '03), reported *S. nigra* (*antacustica*) as occurring in the ear. Schwatze, von Wreden, and Bezold (cited by Plaut, '03) upheld the parasitic theory of this fungus. More recently Hatch and Row ('00), in India, where

ear mycosis is a very virulent disease, reported the occurrence of *Sterigmatocystis nigra, Aspergillus viridescens, A. fumigatus, A. albus, A. glaucus,* and *A. flavescens.* The ear undergoes a serious catarrh, less frequently conditions of purulent discharge. The fungi, *Aspergillus fumigatus* and *Sterigmatocystis nigra,* investigated by Siebenmann ('89), grow poorly, if at all, on the normal epidermis.

There is little mention of fungi appearing in diseases of the nose. Schubert ('85) reported the occurrence of *Aspergillus fumigatus* on surface lesions in the nose. In another incident, a distiller was so afflicted that both the lower and middle nasal cavities were filled with a gray-green secretion of a characteristic odor. A microscopic investigation revealed a hyphomycete with long, single-celled, sickle-shaped conidia. No cultures were made, but Ferdinand Cohn pointed out the similarity of this fungus to *Isaria,* certain species of which are known to be parasitic on insects.

Ceratomycosis is of rare occurrence, and only a few cases have been described. This condition is usually brought about by means of an injury from a falling body infected with fungous spores. The first incident is that reported by Leber ('82), in which a farmer forty-five years old, working on a threshing-machine, was struck in the eye by an oat scale. Berliner and Uhthoff ('83) reported a ceratomycosis caused by a falling pear striking a farmer in the eye. Fuchs ('94) mentions a case of inflammation in the right eye of a miller fifty-three years old and sick with fever, the condition being apparently due to an injury and a later infection with *Aspergillus fumigatus.*

The above-mentioned investigators dealt only with localized diseases of a single tissue. Zenker, in 1861 (cited by Plaut, '03), stated that what had originally occurred as thrush on the mucous membrane of a man, had produced metastases in the brain in the form of multiple abscesses. Grohe, in 1870, injected the spores of moulds into the veins of rabbits and presumably obtained metastases of the inner organs. Michailow ('11) mentions the occurrence in two cases of Asiatic cholera, of fungus-like elements in the cen-

tral nervous system, but he obtained no cultures of the organism.

The spores of fungi, introduced by injection into the blood-vessels, are carried by the blood into all parts of the body. They do not germinate in the blood current itself, but only in certain organs of the animal into which they are conveyed by the blood. The living organs show different degrees of liability to the attack of the fungus, especially when the spores are injected in small quantities. Lichtheim ('82) arranges the susceptibility of the various organs to *Mucor* in the following descending series: kidneys, Peyer's patches, mesenteric glands, spleen, marrow, and the liver. After the death of the animal there is no difference in the rate of germination and development of the fungus in the organs. The development of the fungus is attended by characteristic local derangements, and these produce disturbances of the general health. Sticker ('00) asks the question whether or not the large amount of carbon dioxide formed by the development of the fungus does not cause the injurious effects on the animals. Others believe that a fermentative action plays an important rôle. Spontaneous Aspergillus and Mucor mycoses in internal organs removed from the direct access of air are, to say the least, a doubtful occurrence.

Grawitz ('77) attempted to produce infection in dogs and rabbits by inoculations with spores of *Mucor Mucedo*, *M. racemosus*, and *Rhizopus nigricans*. None of the two hundred animals used died from the effects of these treatments. Experiments of Lichtheim ('82) and Lindt ('86) indicated that *Mucor corymbifer*, *M. pusillus*, and *Rhizopus Cohnii* were pathogenic for certain animals. However, none of the species of *Mucor* and *Aspergillus* when injected into the blood system of animals gave rise to fructifications in the tissues. Lichtheim pointed out that the negative results of other investigators were to be expected, since all species of *Mucor* and *Aspergillus* are not pathogenic. His predecessors had experimented with diverse species, impure cultures, or with fungi inexactly determined.

Birds are very susceptible to aspergillosis and succumb regularly after a time varying with the quantity of spores injected. Rabbits and guinea-pigs are susceptible to a less degree, and these animals can survive when they receive infections of a small quantity of fungous spores. Dogs, cats, and sheep are immune.

More recently Lucet and Costantin ('00) have established the pathogenic nature of *Mucor corymbifer*. Rabbits succumb to the spores of *M. corymbifer* three to twelve days after the injection of the spores, with lesions in the kidneys and mesenteric glands. The same authors affirm the pathogenic properties of *Rhizopus nigricans* (*Rhizomucor parasiticus*). Intravenous and intraperitoneal injections of *R. nigricans* proved fatal to rabbits and guinea-pigs, but subcutaneous injections were ineffective.

The authors above mentioned assert that the intensity of the toxic action of fungi is proportional to the quantity of the fungous spores injected, and that in this manner it differs from that of pathogenic bacteria in which the intensity of the toxic action is independent, to a large extent, of the number of bacteria injected into the animal. The toxic action of fungous spores is apparently not affected by chemical treatment or by heating for a limited time up to the thermal death-point. The fungous spores may germinate, but no multiplication of cells takes place in the tissues; consequently, in experimental mycotic infections there is no secondary generalization. These mycotic colonies are not directly inoculable into other animals, and in order to infect another animal, it is necessary to "produce a new series of spores in contact with the air."

There are a large number of species of *Mucor* and *Aspergillus* of wide distribution. The most common species of *Mucor* is *M. Mucedo* which is non-pathogenic for animals, as is also *Rhizopus nigricans (Mucor stolonifer)*, a very widely distributed species which is often considered pathogenic. The species of fungi given below have been considered as injurious to animals. The greater number of these species have been misdetermined, whereas the toxic action

of certain other species of fungi is questionable. A description will be given only for the more important and confirmed species.

PHYCOMYCETES

MUCOR

M. cornealis Sacc. in Cavara, Centralbl. f. Bakt. I. **72**:23–37. 1914.

This fungus was isolated by Cavara ('14) from a man's eye which had been struck by a piece of dirt. A week after the accident, there developed a ceratomycosis mucorinea, an inflammation of the cornea. A culture of the fungus was sent to Saccardo for determination, who found that it was a new (?) species closely related to *Mucor racemosus* and *M. Regnieri*. It produced injurious effects when inoculated into the blood system of rabbits and guinea-pigs, with the occurrence of lesions in the kidneys. Saccardo's description of this fungus agrees entirely with the descriptions for *M. corymbifer*, including the color of mycelium, the maximum and minimum growth temperatures, and the type and size of sporangia, columella, and spores.

M. corymbifer Cohn, in Schroeter, Kryptogamenflora Schlesien **3**:205. 1886.

Mycelium at first snow-white, later a dull gray, hyphae penetrating the substratum or aërial and ascending, hyaline; hyphae of sporangia racemose, bearing 1–12 sporangia; sporangia pyriform, varying in size from the smallest, 10–20μ, to the largest, 70μ in diameter; columella conical to hemispherical, finally papillate, brown; spores hyaline, elliptical, $3 \times 2\mu$, to ovoid, $4 \times 6.5\mu$.

This species was first isolated by Lichtheim ('82) in his laboratory, growing with *Rhizopus Cohnii* on a decoction of bread. It was reported by Paltauf ('85) as occurring in the principal organs of a man dead from generalized mycosis; by Huckel in 1885, and Siebenmann in 1889, as associated with *Aspergillus fumigatus* in the external auditory canal; also in two cases of pulmonary mycosis, by Fürbringer ('76). It has an injurious action on rabbits and guinea-pigs, accord-

ing to Lichtheim ('82), and Berthelat ('03). This species is considered by Lucet and Costantin, ('01) as including several varieties known as *M. ramosus* Lindt, *M. Truchisi* Lucet & Cost. and *M. Regnieri* L. & C.

M. Mucedo L. Sp. Pl. **2**:1655. 1764.

Mucor Mucedo is found, in general, on all organic substances of vegetable and animal origin in the process of decomposition, and more particularly on the excrement of animals. It is extremely common in the state of a saprophyte, and has been reported at various times as occurring on man and other animals; in mycosis of man by Hiller in 1874 (cited by Plaut, '03) and Fürbringer ('76). In these observations the determination of the fungus was not sufficiently established, and the demonstrated virulence on animals was possibly due to impure cultures, since Berthelat ('03) finds that it is without action on rabbits and guinea-pigs.

M. Regnieri Lucet & Cost. Archiv. d. Par. **4**: 366–384. 1901.

This fungus was isolated from an epidermal lesion on a horse affected with *Oospora (Trichophyton),* and according to Costantin ('01), was non-pathogenic for rabbits. This organism evidently had nothing to do with the diseased tissue from which it was obtained. Costantin later regarded this fungus as identical with, or as a variety of, *M. corymbifer.*

M. Truchisi Lucet & Cost. Archiv. d. Par. **4**:366–384. 1901.

A culture of this species of *Mucor,* obtained by Lucet ('01) from an epidermal lesion on a horse affected with *Oospora (Trichophyton) minimum,* was toxic for rabbits. It is possible that this fungus played no part in the observed affection, and more recent studies of this organism led Costantin to consider it as identical with *M. corymbifer.*

M. (Rhizomucor) parasiticus (Lucet & Cost.) Sacc. & Syd. in Sacc. Syll. Fung. **16**:385. 1902.

Rhizomucor parasiticus Lucet et Cost. Rev. Gén. Bot. **12**:92. 1900.

This species was observed by Lucet and Costantin ('00) in a woman affected with pseudo-pulmonary tuberculosis. Cul-

tures were made of this fungus and it was found to be a new (?) species which they called *Rhizomucor parasiticus*. Lucet and Costantin in their description of this particular fungus, assert that it varies from *Rhizopus nigricans* only in having branched sporangiophores. This character alone is not sufficient to establish a new genus, since branched conidiophores occur in many species of *Mucor*. The writer has observed branched conidiophores in cultures of *Rhizopus nigricans*. Lucet and Costantin evidently obtained this latter fungus as a contamination of their culture medium, since they examined only the sputum of the diseased person.

M. pusillus Lindt, Archiv f. exp. Path. **21**:269–298. 1886.

This species of *Mucor* was isolated simultaneously with *M. corymbifer* (*M. ramosus* Lindt) by Lindt ('86). The spores produced injurious effects when injected into rabbits. The same species was reported by Jakowski ('89) in a case of otomycosis, but this determination is considered doubtful.

M. racemosus Fres. Beitr. z. Myk. 12. 1850.

This species is very frequent on decaying organic substances, such as vegetable debris, meat, and insect cadavers. The fungus found by Bollinger, in 1880, in fifteen instances of mycoses in birds, and determined as *M. conoides* or *M. racemosus*, is probably identical with *Aspergillus fumigatus*. According to Berthelat ('03), it is without action on rabbits and guinea-pigs.

M. ramosus Lindt, Archiv f. exp. Path. **21**:275–284. 1886.

Mucor ramosus Lindt is very closely related to *M. corymbifer*, and differs (?) from it only slightly in the size and shape of the spores. According to Lindt ('86), it is toxic for rabbits.

M. septatus Bezold, in Siebenmann, Schimmelmykosen d. Ohres 97. 1889.

Rhizomucor septatus Lucet et Cost. Rev. Gén. Bot. **12**: 81–98. 1900.

Mucor septatus was discovered by Siebenmann ('89) in the external auditory canal, evidently as a saprophyte. The description given for this species is incomplete, and no cul-

tures were made. Fisher regards this fungus as identical with *M. racemosus,* which is non-injurious to animals.

RHIZOPUS

R. niger Ciaglinski & Hewelke, Zeitschr. f. klin. Med. **22**:626–632. 1893.

This species, isolated by Ciaglinski (cited by Guéguen, '08) from a case of "black-tongue" and determined as *Mucor niger,* had an optimum growth temperature of 25–27°C., and was non-pathogenic for animals. The incomplete description does not permit of an exact determination, and it is possible that Ciaglinski was dealing with *R. nigricans.*

R. Cohnii Berl. & De Toni, in Sacc. Syll. Fung. **7**:213. 1888.

According to Lichtheim ('82), this fungus, found with *Aspergillus fumigatus* on bread, has an injurious effect on rabbits. Its occurrence has not been reported in conditions of mycosis.

MORTIERELLA

Neumann mentions an interesting case of the parasitism of a species of *Mortierella* (?) in a cat which had died by asphyxia, presumably as a result of a fungous growth in the trachea. Costantin ('92) considered the fungus a new (?) species, probably belonging to *Mortierella,* since the spores of the known species of *Mortierella* do not germinate at blood temperature, 37°C. This determination cannot be accepted, since it depends exclusively on the presence of echinulate spores.

ASCOMYCETES

ASPERGILLUS

A. aviarius Peck, N. Y. State Mus., Ann. Rept. **44**:137. 1891.

This fungus was found by Peck ('91) in the body of a canary that had died after being sick a few days. No culture was made, and according to Wehmer, it is the same as *A. fumigatus,* for the determination was made from old fungous elements.

A. bronchialis Blumentritt, Ber. d. deut. bot. Ges. 19:442–446. 1901.

A species of *Aspergillus* was discovered by H. Chiari, in the trachea of a diabetic patient. Blumentritt ('01, '05) gives a full account of this fungus which agrees with the description of Wehmer for *A. fumigatus*. Blumentritt admits that *A. bronchialis* is very closely related to *A. fumigatus* and can be distinguished from it only by a few minor physiological characters.

A. candidus Link, Observationes 1:65. 1809.

A. candidus was obtained from a patient affected with otitis, in which case it appeared as a saprophyte, its optimum growth temperature being 25°C.

A. flavus Link, Observationes 1:14. 1809.

In pure cultures on various media usually of a yellow-green to a light brownish green color; mycelium sterile, always grayish white and even hyaline; conidiophores not very conspicuous, usually 500–700μ in length, 7–10μ thick, the terminal swelling colorless, spherical to clavate, 30–40μ in diameter, with conidia about 85μ; sterigmata undivided, 20 $\times$ 6μ, crowded, arranged radially; conidia varying in size, spherical, smooth, rarely papillate, 5–7μ in diameter.

This species, frequently found in the ear as a saprophyte, and *A. flavescens* Wreden, are considered by Siebenmann ('89) as identical. According to Ribbet, the spores of this fungus are toxic for rabbits. Wreden (cited by Plaut, '03) considered *A. flavescens* as a variety of *A. glaucus*, but new descriptions of the former species are lacking, and in recent literature we find *A. flavescens* appearing as a synonym of *A. flavus*.

A. fumigatus Fres. Beitr. z. Myk. 81. 1850.

A. nigrescens Robin, Veg. Par. 518–528. 1853.

Forms a greenish layer in fruiting cultures; mycelium much branched, 2–3μ in diameter; conidiophores scarcely different from the hyphae, formed in dense tufts, 100–300μ long, 5–6μ thick; terminal swelling small, green, clavate, ta-

pering gradually from the base, 10–20μ thick, with conidia 30–40μ thick; sterigmata 6–15μ long; conidia formed in chains, vertically arranged, not radially, spherical, rarely oval, 2–3μ in diameter, at first hyaline, then gradually changing from yellow to green and finally to brown.

This species has been reported in most cases of mycosis as being very frequently found in the respiratory tract of birds. It affects the eye, ear, and other parts of the body if they are accidentally injured or become diseased, as well as the lungs of men who feed birds in the manner previously mentioned. It occurs in cases of ceratomycosis, according to Leber ('82) and Uhthoff ('83), and in otomycosis reported by Siebenmann ('89). Siebenmann considers *A. nigrescens* Robin as identical with *A. fumigatus*. The species is very toxic for rabbits, guinea-pigs, birds, and monkeys. Dogs and cats, however, are not affected.

A. fontoynonti Guéguen, Compt. rend. Soc. Biol. **66**:1052. 1909.

Under the name of "nodosités juxta-articulaires," Jeanselme has described a disease which occurs in Indo-China and Madagascar. Two of the cultures which were made closely resemble *A. Tokelau* in growth characters. The description, as given by Guéguen ('09), is that of a slow-growing *Aspergillus*, producing meager fructifications of a greenish white color after a growth of three weeks on Raulin gelatin medium. No liquefaction of gelatin takes place before fourteen days, and only a slight liquefaction after a month. Its optimum growth temperature is 22–25°C., but no development takes place at 37°C. From these observations it is difficult to understand why an injection of spores of this fungus should prove fatal to rabbits and guinea-pigs.

A. glaucus Link, Observationes **1**:67. 1809.

This species has been reported as the green mould occurring frequently in the air sacs of birds, but more precise observations tend to show that these parasites are mostly *A. fumigatus*.

A. malignus Lindt, Archiv f. exp. Path. **25**:257–271. 1889.

Spores of this fungus, found by Lindt in a case of otitis, when introduced into animals, produced death in a few days after injection. However, according to Wehmer ('98), *A. malignus* Lindt is evidently *A. fumigatus* Fres.

A. nigricans Cooke, Jour. Quekett Micr. Club II. **2**:140. 1885.

This species, according to Siebenmann, is *A. fumigatus* and *A. nigricans* Wreden is *Sterigmatocystis nigra* Van Tieg. Under the name of *Otomyces purpureus* Wreden describes what he considered as the ascospore form of *A. nigricans;* but according to Gedoelst ('02) these forms of development were nothing more than pseudo-perithecia of *Sterigmatocystis nidulans.* Wehmer ('98), however, considers *A. nigricans* Cooke only as *Sterigmatocystis nigra* Van Tieg.

A. repens (Corda) Sacc. in Michelia Commentarium Mycologicum **2**:577. 1882.

This species was reported by Siebenmann ('89) as having been present at three different times as a saprophyte in the ear. It is more likely that Siebenmann was dealing with *A. glaucus* which differs but slightly from the descriptions given for *A. repens.*

A. Tokelau Wehmer, Centralbl. f. Bakt. I. **35**:140–146. 1904.

Mycelium hyaline, very delicate, 1–2μ thick, branched, growing between the epidermal elements, septate; conidiophores usually small, 100μ, sometimes 500–900μ, long, with a diameter varying from 8–12μ in the smallest to 30μ in the largest, hyaline, smooth; terminations light brown to yellow; pedicel simple, rarely irregularly branched, hyaline, smooth, thin-walled, 5–13μ wide; sterigmata undivided, flask-shaped, more or less numerous, 5–9 $\times$ 2–3μ, usually arranged radially; conidia globose, rarely globose to ellipsoidal, echinulate, isolated or only in short chains, size varying from 3–12μ in diameter.

The Samoa disease or tokelau, a skin disease occurring in certain Oceanic islands of the South Sea—Fiji, Gilbert, and

Solomon Islands—was described by Patrick Manson as "tinea imbricata." In the characteristic lesions Tribondeau found spore-bearing organs similar to the conidiophores of *Aspergillus,* but he was not sure of this determination and therefore called the fungus "*Lepidophyton.*" This, however, did not clear up the situation. Fortunately, Wehmer ('04) obtained a culture of this organism and found it to be a new species of *Aspergillus.* The fungus develops in the epidermal tissues of the body and extremities. The lesions have much the appearance of ringworm and also occur in superficial cancer ulcerations.

STERIGMATOCYSTIS

S. nigra Van Tieg. Soc. Bot. Fr., Bul. **24**:102. 1877.

Evidently a species easily recognized by the dark brown color of the conidial masses; conidiophores very crowded, 2 mm. high; pedicel about 18μ in diameter, with walls 2μ thick, hyaline; terminations globose to subglobose, 80μ in diameter, with conidia 130μ in diameter; numerous sterigmata on all sides, radially arranged, very slender, branched; primary sterigmata clavate, 26 $\times$ 4.5μ; secondary sterigmata 8 $\times$ 3μ; conidia in long chains, small, spherical, smooth, or echinulate in old cultures, 2.5–4.5μ, violet-brown; hyphae 3μ in diameter.

This species was cited for the first time as a parasite by Cramer, while soon after Fürbringer ('76) reported the same fungus occurring in the lungs of a man. Wreden describes a mould frequent in otomycosis which he termed *Aspergillus nigricans,* but according to Siebenmann ('89) it is *Sterigmatocystis nigra,* probably the same fungus that Costantin and Lucet ('03) reported under the name of *S. pseudonigra.* Lucet, Costantin, and others have found that *S. nigra* is non-pathogenic for animals.

SACCHAROMYCES

S. anginea Troisier & Achalme, Archiv. d. Méd. Exp. et d'Anat. Path. **5**:29–37. 1893.

The first observation of a parasitic yeast in man is that of Troisier and Achalme ('93) in a patient with a condition

clinically resembling thrush. A microscopic examination of substances taken from the pharynx revealed the presence of ovoid cells 8–9 × 5–6μ, united in groups of eight or ten. Budding took place only at the extremities of the cells. In culture asci with four globose ascospores, 2μ in diameter, were formed. There was no liquefaction of gelatin and no film formation in liquid nutrient solutions. Saccharose present in quantities less than 10 per cent in nutrient solutions was completely changed to alcohol.

S. granulatus Vuillemin & Legrain, Archiv. d. Par. 3:237–268. 1900.

This yeast was found by Vuillemin and Legrain in a tumor of the inferior maxillary region of a man. It appears in the form of oval or elliptical cells 2–10 × 3–4μ, with a membrane covered with isolated granulations or striations disposed in regular lines. The cells form one, rarely two, buds and enclose fat bodies of a red color. Chlamydospores are sometimes present in cultures. In liquid media the fungus does not produce a film but forms a red sediment. It does not liquefy gelatin. Two to four spherical or elliptical spores appear in each ascus. This yeast is slightly pathogenic for the rabbit when inoculated intraperitoneally.

SACCHAROMYCOPSIS

S. guttulatus (Robin) Schiönning, in Robin, Veg. Par. 327–331. 1853.

This species was discovered by Remack and Robin, and later studied by Casagrandi and Wilhelmi. It is normally present in the stomach and intestines of the rabbit, and of certain birds and reptiles.

The cells of this fungus are very large, 6–16 × 2–4μ, oval or more or less rectangular, and united in groups of two or three. Budding takes place at the two poles of the cells. The optimum growth temperature is 35–37° C. No film is observed in liquid media. Ascospores, one to four in each ascus, are present only in the excrement of the rabbit. The spores are oval with a double membrane. At the beginning of germination, the exospore breaks at one end or at the side of the

ascospore, and then growth takes place by budding. This yeast ferments dextrose and inverts saccharose. According to Casagrandi, it is pathogenic for the guinea-pig and rabbit by subcutaneous injections.

ENDOMYCES

E. albicans Vuillemin, Compt. rend. Acad. Paris **127**:630–633. 1898.

The organism producing thrush has been variously classified as *Sporotrichum* Gruby (1842), *Aphtophite* Gruby (1844), *Oidium* Robin (1853), *Stemphylium* Hallier (1866), *Syringospora* Quinquaud (1868), *Mycoderma* Grawitz (1877), *Saccharomyces* Reess (1877), *Monilia* Plaut (1888), *Dematium* Laurent (1890), and *Empusa* Henri (1896). In its parasitic life *E. albicans* develops a more or less extended membranous layer, at first white, then gray, on the mucus of the primary digestive passages—mouth, pharynx, and oesophagus. This membrane, which attains a thickness of 1–2 mm., does not adhere to the mucus and is easily detached. A microscopic examination shows it to be made up of filaments, usually from 3–5 $\times$ 50μ. The terminal cells may often attain a length up to 600μ. According to Linossier and Roux ('99), this organism does not grow in saliva. This peculiarity accounts for the fact that thrush occurs only in infants, more frequently during the first few months of life when the salivary secretion has been insufficiently established, and, in general, in all cases of infection accompanying a diminution of the secretion of saliva.

On different media the fungus develops either by budding, like a yeast, or by the elongation and division of cells, as in *Monilia*. On carrot the mycelium is very well developed, whereas in nutrient liquids only yeast cells are present. According to Vuillemin, the filamentous form is the normal method of vegetation, the yeast cells appearing in conditions of malnutrition. In sugar solutions at a temperature of 30–35°C., chlamydospores form at the end of the filaments.

The asci were discovered by Vuillemin ('98) in old cultures on beet. They appear as large, ovoid or elliptical asci, 4–5μ in diameter, formed by a lateral or terminal bud-

ding of the mycelium or derived by the germination of chlamydospores. The asci contain four ascospores, formed in a manner similar to those of *E. capsularis*, slightly reniform, 2.8–3.5 × 1.75–2 × 1.2–1.4μ, with a thick membrane. The germination of these ascospores has not been observed.

Development takes place at a temperature of 20–39°C. on slightly acid, solid, or liquid media. In sugar solutions and fruit juices growth takes place slowly, with the formation of a flocculent deposit but with no film on the surface. The fungus coagulates milk after 20–30 days and ferments dextrose slightly. Certain authors believe that there exist many varieties of *E. albicans*, only some of which have the function of producing spores.

Castellani ('11) isolated from cases of bronchomycosis in Ceylon, twenty-two strains of *Endomyces* which, in microscopic appearance and cultural characters, closely resembled *E. albicans*. Fourteen strains were identical and corresponded to *E. tropicalis*, whereas the other eight strains differed from *E. tropicalis*, and from each other. The behavior of the different strains, especially toward sugar solutions, indicated that there are nine different species. Castellani believed that six of these species were parasitic, but he was not certain about the other three. It may be possible that a similar condition as to the plurality of species of *Endomyces* affecting man also exists in the temperate zone.

Before describing the better-known pathogenic yeast-like fungi, it may be well to consider first the development of the parasitic theory of cancer. This disease, more than any other human ailment, has been a fruitful field for the discovery of such forms as resemble yeasts.

The one common characteristic of cancers is the power of cell proliferation, and the problem that many scientists to-day are undertaking is the causes underlying such proliferation. Many investigators take the view that cancer has some specific and demonstrable cause.

By the continued division of the carcinoma cells, masses of tissue are formed which grow out into lymph channels. Mechanically obstructing the normal activities of surround-

ing tissues, or breaking through such tissues, they give off small groups of free cells which may be carried by the blood to various parts of the body, there to set up independent growths (metastases). With the local disturbances caused by such abnormal growths, many normal cells are killed, whereas the cancer cells themselves undergo hyperplasia and hypertrophy. The progress of cancer is accompanied by the degenerating of various kinds of cells, and these different structures are the things which have been interpreted by various investigators as x-bodies, amoebae, coccidia, protozoa, or other organisms.

Many of the structures thus interpreted as organisms are characterized by capsules which some investigators have interpreted as parts of an invading organism. Cell invasions are common in cancer tissue, but the capsules are only condensations of the invaded protoplasm. Pianeze ('96) observed similar bodies in the nuclei of cancer cells, and interpreted both these and the cytoplasmic forms as colloidal degenerations of the chromatin and cytoplasm.

Although these cell inclusions in human cancer cannot be considered as organisms, it does not follow that real organisms are not present. Later stages of the disease are particularly suitable for secondary infection, and exposed surface lesions form a suitable medium for the growth of bacteria, yeast-like organisms, and other fungi.

San Felice ('95) made a series of inoculation experiments on animals with yeast-fungi obtained from various sources, principally from the juice of fruits. During the course of these experiments he found one species, *Torula neoformans*, which, if inoculated into animals, produced the formation of neoplasm. The same author ('96) also discovered *Cryptococcus lithogenes* in a lymphatic ganglion of a cow that died as a result of a primary carcinoma of the liver. From this observation he seemingly obtained the confirmation of his ideas on the pathogenic rôle of cryptococci in the formation of malignant tumors. His parasitic theory of cancer was based on the presence of cryptococci in tumors, the isolation of cryptococci

from diseased tissues, and the results of inoculation experiments on animals.

The presence of cryptococci in tumors has been mentioned by a large number of authors, but the tumors thus parasitic do not all pertain to the type of malignant tumors. Binaghi ('96) investigated fifty-three cases of epithelioma and isolated parasitic organisms in forty instances. The failure to obtain parasites in the remaining thirteen, according to this author, may be due to the fact that the part examined was either in an early stage of development or not infected. These organisms, identical with cryptococci in their morphological and physiological characters, were not found in other pathological or normal tissue. Consequently, they were considered as the specific cause of epithelioma. Maffucci and Sirleo ('98) obtained ten or more cultures of yeasts from the thirty-nine tumors which they examined. Only one was pathogenic for guinea-pigs, and in these animals it produced fibrinous pneumonitis and abscesses under the skin or in the kidneys. The results indicated that a new formation of sarcoma tissue did not take place. Roncali, Corselli, and Plimmer obtained cultures of fungi from malignant tumors, but only in a few cases were they pathogenic for animals. Leopold ('00) reported having isolated pure cultures of cryptococci from over 80 per cent of the non-ulcerated tumors investigated, the cultures having been obtained from the center of the diseased tissue.

Loeb, Moore, and Fleisher ('13) were unable to confirm the results of Leopold. Of the seventeen tumors examined, only one gave a culture of a yeast-like organism. In no case of human cancer has the causative significance of a microörganism so far been proved. Moreover, Busse ('03) was never able to obtain a single culture of *Cryptococcus* from non-ulcerated tumors.

No one has been able to demonstrate the development of tumors histologically comparable to cases of sarcoma, by the inoculation experiments on animals with cultures of *Cryptococcus*. By inoculation of *C. tumefaciens* in the white rat, Curtis obtained results in which "la tumeur etait iden-

tique a celle de l'homme, c'est-a-dire constituée par une infiltration du parasite dans les mailles du tissue cellulaires." This, however, does not imply that Curtis obtained a sarcoma-like tumor.

FUNGI IMPERFECTI

CRYPTOCOCCUS

The species of *Cryptococcus* here given were reported as having been obtained from tumors, but their rôle in the production of these malformations has not been determined.

C. Corsellii (Corselli & Frisco) Neveu-Lemaire, in Corselli & Frisco, Centralbl. f. Bakt. I. **18**:368–373. 1895.

This species was isolated by Corselli and Frisco ('95) from a sarcoma of the mesenteric ganglia of a man. This fungus has dark cells, globose, and of variable dimensions. It is easily cultivated on gelatin, agar, and bouillon, neutral or alkaline. It can give rise to a slight fermentation and is pathogenic for guinea-pigs, dogs, and rabbits, by intraperitoneal inoculations.

C. degenerans Vuillemin, in Roncali, Centralbl. f. Bakt. I. **18**:353–368. 1895.

Roncali ('95) observed this species in the ganglion of the armpit of a woman affected with cancer of the breast. In the cancer the cells are globose, rarely oval or reniform, isolated or in groups. In cultures the cells are globose or elliptical. On sugar nutrient liquids this fungus produces a film. On gelatin the colonies are irregular in outline and of a light yellow color. Gelatin is not liquefied and saccharose is not fermented. It is pathogenic for the guinea-pig by intraperitoneal injections. The autopsy revealed an abscess of the mesenteric ganglia, which was produced by degeneration products; the normal cells were rarely found in these lesions.

Cryptococcus of Gotti & Brazzola, in Guilliermond, Les Levures. 1913.

This species was found by Gotti and Brazzola in a myxosarcoma of the nasal fossa of a horse. The cells are

of variable dimensions, round or oval, with granular contents, enveloped by a membrane of double contour and a mucilaginous capsule that is often stratified. On gelatin or agar, the colonies are white with denticulate margins. Acid gelatin is liquefied. It is pathogenic for the guinea-pig but not for other animals.

C. farciminosus Rivolta & Micellone, in Fermi & Aruch, Centralbl. f. Bakt. I. **17**:593–600. 1895.

This species has been considered as the parasite of "African glanders." The cells are globose or oval, sometimes acuminate at the two poles. It grows with difficulty on all media. Fermi and Aruch have described the globules, which they considered ascospores, in the cells of this yeast.

C. Gilchristi Vuillemin, in Gedoelst, Les Champ. Par. 1902.

This fungus was obtained by Gilchrist in a case of scrofulodermatitis. It is only slightly pathogenic for animals.

C. granulomatogenes (San Felice) Vuillemin, in San Felice, Zeitschr. f. Hyg. **44**:364–396. 1903.

This fungus was discovered by San Felice in the lung nodules of a hog. It is only slightly pathogenic for animals.

C. hominis (Busse) Vuillemin, in Busse, Die Sprosspilze, in Kolle & Wasserman, Handbuch 1:631–700. 1903.

This species was discovered by Busse ('03) in periosteal lesions of the tibia of a woman. *In situ* the oval or globular cells are united in variable numbers in a substance of a homogeneous aspect, constituting a sort of common capsule. This homogeneous substance is not present in cultures. The cells have a double-contoured membrane that becomes thicker with the age of the culture.

It is easily cultivated on all media between 15 and 38°C. In liquid media it forms a deposit of yeast cells and a thin film on the surface. It does not liquefy gelatin. On potato the colonies rapidly unite to form a thick white layer. The fungus ferments dextrose and is pathogenic for rabbits, white mice, and dogs.

C. linguae-pilosae (Raynaud & Lucet) Vuillemin, Lucet, in Archiv. d. Par. **4**:262–287. 1901.

This fungus was discovered by Raynaud and Lucet in the disease of "black-tongue." Lucet ('01) in his experimental studies demonstrated that this fungus did not reproduce the disease. According to Guéguen and Thaon, this yeast acts only when associated with *Oospora lingualis*. There is, then, in these two fungi a sort of symbiotic relation.

This organism has spherical, ovoid, or elliptical cells, 4–17 × 6μ. It grows on most media and in liquids forms a white film after ten hours at 37°C. It ferments glucose and levulose, with the production of alcohol and carbon dioxide. Development is accompanied by the production of acid, but no liquefaction takes place on gelatin. It has a slight pathogenic action on certain animals and is without effect on guinea-pigs and rabbits by subcutaneous or intraperitoneal inoculations.

C. lithogenes (San Felice) Vuillemin, in San Felice, Zeitschr. f. Hyg. **21**:32–58, 394–420. 1895–96.

San Felice isolated this parasite from the lymphatic ganglia of a cow that died as a result of primary carcinoma of the liver, with extensions of the infection to the entire lymphatic system. In the tissues the cells are more or less spherical, of variable dimensions, enclosed by a refringent membrane. This species grows well on all media. On glucose bouillon it forms an abundant deposit of yeast cells and often a film on the surface. It does not liquefy gelatin. It forms white yeast-like colonies on agar, and on potato the colonies become dark brown in color. It is pathogenic for the guinea-pig, mouse, and sheep.

C. niger (Maffucci & Sirleo) Vuillemin, in Maffucci & Sirleo, Zeitschr. f. Hyg. **27**:1–30. 1898.

This species was discovered by Maffucci and Sirleo ('98) in a pulmonary lesion of a guinea-pig inoculated with the liver of an embryo taken from a tubercular mother. It is pathogenic for animals only after a long time. The cultures sterilized by heat are toxic for guinea-pigs.

C. Tokishigei Vuillemin, in Tokishige, Centralbl. f. Bakt. I. **19**:105–113. 1896.

This fungus is considered by Tokishige ('96) as producing in Japan the disease of horses known as "farcin." It is non-pathogenic for rabbits, guinea-pigs, and dogs, by subcutaneous inoculations. The pathological products of this fungus have more effect on animals than inoculations of the cultures. Inoculation of this organism in the horse produces lesions after varying lengths of time, but without causing the death of the animal.

OOSPORA

The longest-known fungous disease of the skin is favus, which previous to 1839 included a large number of different skin affections. When its contagious nature was discovered by Schonlein, investigators began searching for the relation of fungi to skin diseases. Heusinger in 1826, and Remak in 1837 (both cited by Virchow, '56) observed mould-like filaments in the scales of tinea. The latter author in 1847 succeeded in growing cultures on apple, again producing the characteristic lesions, presumably by inoculating his arm with these cultures. Gruby ('43) independently discovered three different fungi associated with as many types of ringworm. Two of these fungi were *Oospora*, and the other was *Sporotrichum (Microsporon) Audouini*. His description of these fungi was very good, yet no one at that time suspected that, under the name of *Porrigo decalvans*, he was describing fungi which were the cause of ringworm. Very little attention was given to these discoveries until Sabouraud began his investigations in 1892, which differentiated the many varieties of *Oospora (Trichophyton)* and *Sporotrichum (Microsporon)*.

Oospora is often associated with mycosis of the lung and with *Endomyces albicans* in the mouth. *Oospora pulmonalis* brings about a degeneration on the surface of the trachea and walls of the bronchia, where white granules are found similar to those caused by *Actinomyces*. The alveolar structure is filled with mycelium, and in certain places real abscesses are found constituted by degenerated tissue filled with mycelial debris. In lesions of the mouth, Roger, Bory,

and Sartory ('09) discovered *Oospora buccalis* associated with *Endomyces albicans*. In other diseases caused by *Oospora*, the fungus may occur as a saprophyte or as a parasite. These fungi are very closely related to each other and cannot always be differentiated sharply.

Oospora of *Trichophyton*.

Gruby ('43) was the first to give a clear description of the Oospora parasite that causes epidemic and endemic diseases of the skin. The morphology of these fungi has been studied in the lesions which they produce and in cultures on artificial media. This fungus develops into filaments composed of short segments. The dimensions of the cells in the same filament are approximately equal. Their diameter remains invariably the same for the same species, but the length of the cells may vary 1 to 2μ. The cells may be spherical or oval, the mycelial filament being moniliform and easily dissociated into its different elements. When the mycelial cells are cubical, the filaments are more or less extended and not easily dissociated.

The classification of the varieties affecting man, according to the infection, falls into two groups. The endothrix group contains the varieties of human origin which develop in the hair between the cuticle cells and grow exclusively within the hair structure. The ectoendothrix group of parasites, probably of animal origin, develops in the hair and proliferates in the follicle outside.

More often the scheme of Sabouraud is used, in which are considered the mode of infection and principally the cultural characters of the isolated fungus when grown on "proof agar." There are over thirty varieties of *Oospora* of *Trichophyton*, and their differences are chiefly cultural.

Matruchot and Dassonville ('99), reasoning from analogies, place the parasites of *Trichophyton* in the *Ascomycetes*, in the family *Gymnoascaceae*. The asexual type of development in the *Gymnoascaceae*, according to these investigators, can serve to characterize these fungi with the same degree of precision as the complete forms. The demonstrated affinity

of *Oospora tonsurans* with *Ctenomyces* rests on the similarity of characters in the conidial stage of development. In old cultures of *O. tonsurans* may be found multicellular chlamydospores, spindle-spores, and serrate septate hyphae. This fungus, according to Matruchot and Dassonville, is an imperfect form of a species of *Ctenomyces*, still unknown, which has adopted a parasitic mode of development and consequently has lost the faculty of producing perithecia and ascospores. The serrate spiral hyphae, present in cultures of *O. tonsurans*, are considered as traces of asci formation.

O. tonsurans (Malmsten) Sacc. & Trav. in Sacc. Syll. Fung. **20**:236. 1911.

The mycelium of this fungus usually fills the entire hair without having passed through the cuticle. The filaments are more often simple, rarely dichotomously branched. The fungus is made up of squarish cells 4–5μ long, arranged in chains that follow the direction of the hair.

O. porriginis (Mont. & Berk.) Sacc. Syll. Fung. 4:15. 1886. *Oidium porriginis* Robin, Veg. Par. 477–488. 1853.

Gruby ('43) demonstrated that the fungous parasite which he had independently found in favic lesions, was the cause of the affection, and in the following year made successful inoculations with this fungus in the human skin and the skin of animals. In 1845 Remak separated the fungus from the genus *Oidium* to which it had been assigned, and created the genus *Achorion*, with the name *Achorion Schönleinii* for this specific fungus. The characteristic lesion is a small yellow disc with a cup-like depression in the center. Both in color and in shape, it resembles a honeycomb, hence the name which comes from the Arabic *Sahafts*, meaning honeycomb. In the middle ages the disease was called tinea, which name is still retained. Matruchot and Dassonville ('99) also consider *O. porriginis* as belonging to the family *Gymnoascaceae*, but this classification cannot be regarded seriously.

SPOROTRICHUM

S. (Microsporon) Audouini Gruby, Compt. rend. Acad. Paris **17**:301–303. 1843.

Sixty to 65 per cent of the fungous affections of the scalp are caused by *Sporotrichum* of *Microsporon*, including eleven varieties which are divided by Sabouraud into two groups: those of the *Sporotrichum Audouini* type which give slow-growing cultures on artificial media, and those of animal origin which yield rapidly growing cultures. The disease, frequently derived from domestic animals, rarely attacks the glabrous skin, and contagion is more frequent from case to case. At least four varieties of *Sporotrichum* are parasites common to man and animals.

Upon microscopic examination of the diseased hair, the fungus appears in crowded cells, 2–3μ in diameter, irregularly arranged so as to form a continuous covering of the hair without penetrating the cuticle. In the interior we find delicate parallel filaments of large cells. In infection with *Microsporon* the growth of the fungus progresses from the tip of the hair to the lower parts.

S. Furfur (Robin) Sacc. Syll. Fung. **4**:100. 1886.

An affection of the cuticle, called "tinea versicolor," is characterized by the yellowish or brownish discoloration of the lesions, which at one time were classed with the group of pigmentary stains. The color of the lesion is subject to great variation, not merely in different patients, but in different regions of the same patient. This affection caused by *S. Furfur* was first discovered by Eichstedt in 1846. Little is known of the mycological characters of this parasite.

S. (Microsporon) minutissimum Sacc. in Gedoelst, Les Champ. Par. 1902.

An epidermomycosis, erythrasma, presenting some points of resemblance to tinea versicolor, is characterized by brownish scaly patches which appear usually in the genitocrural region. The elements of this species are very small, and in preparations, appear as spores and threads of mycelia arranged almost in the same manner as the elements of *S. Furfur*.

The recognition of sporotrichial infection other than those occurring in skin diseases, is of recent date. The infection,

in a case described by Schenk in 1898, started in the index finger and led to the formation of a series of subcutaneous abscesses connected by a chain of chronic lymphangitis along the arm. This new parasitic fungus was obtained by cultures from the lesions. In 1906 Beurmann (cited by Pinoy, '11) again called attention to this parasite occurring in multiple, widely distributed, gummatous lesions. *Sporotrichum* affects not only the skin and subcutaneous tissue, but also the mucous membrane. Intramuscular and periosteal gummas, and even pulmonary abscesses may be caused by this fungus.

GLENOSPORA

G. Graphii (Siebenmann) Vuillemin, Compt. rend. Acad. Paris **154**:141–143. 1912.

Verticillium Graphii Harz & Bezold, in Siebenmann, Die Schimmelmykosen d. Ohres 95. 1889.

This fungus has been reported by Hassenstein, Steudener, Bezold, and Siebenmann as occurring in otomycosis. In seven cases of otomycosis *Verticillium* has been incriminated four times. This botanical classification of the fungus was not certain, and has not been verified in later investigations. Siebenmann considers Steudener's *Trichothecium*, Hallier's *Stemphylium*, and Harz and Bezold's *Verticillium*, as identical organisms. Vuillemin ('12) followed the development of the above fungus in culture and was able to explain the divergent opinions as to its identity. No degree of regularity in form and position is attained by the conidia, which are dark, one-celled, and irregularly inserted on the mycelium like the conidia of *Glenospora* Berk. & Curt. This then eliminates as parasites of man the genera *Stemphylium*, *Cephalothecium*, *Verticillium*, and the pseudo-genus *Graphium*.

The species of fungi mentioned above may be summarized in the following manner:

PHYCOMYCETES

MUCOR

M. cornealis Sacc. is *M. corymbifer* Cohn.

M. corymbifer Cohn has proven toxic for rabbits and

guinea-pigs. It occurs frequently as a saprophyte.

The occurrence of *M. Mucedo* L. in instances of mycosis is doubtful; it is non-pathogenic for animals.

M. Regnieri Lucet & Cost. is *M. corymbifer* Cohn.

M. Truchisi Lucet & Cost. is *M. corymbifer* Cohn.

M. parasiticus Lucet & Cost. (Sacc. & Syd.) is *Rhizopus nigricans.*

M. pusillus Lindt has not been reported in cases of mycosis.

The occurrence of *M. racemosus* Fres. in cases of mycosis is doubtful. It is non-pathogenic for animals, and those instances of mycosis in which *M. racemosus* Fres. were reported are probably due to *Aspergillus fumigatus* Fres.

M. ramosus Lindt is *M. corymbifer* Cohn.

M. septatus Bezold, as reported in cases of mycosis, is *M. racemosus* Fres.

RHIZOPUS

R. niger Ciaglinski & Hewelke is *R. nigricans.*

R. Cohnii Berl. & De Toni has not been reported in cases of mycosis; it is toxic for animals.

MORTIERELLA

The determination of Costantin that a species of *Mortierella* was present in a mycosis of a cat has not been accepted.

ASCOMYCETES

ASPERGILLUS

A. aviarius Peck is *A. fumigatus* Fres.

A. bronchialis Blum. is *A. fumigatus* Fres.

A. candidus Link has been reported as a saprophyte.

A. flavus Link is also a saprophyte.

A. fumigatus Fres. is frequently found in lung mycosis, more particularly in birds. Most cases of mycosis are due to this species of *Aspergillus.*

A. fontoynonti Guég. is a parasitic fungus that produces epidermal lesions. It is toxic for animals.

Fungi reported under the name of *A. glaucus* Link are *A. fumigatus* Fres.

A. malignus Lindt is *A. fumigatus* Fres.

A. nigricans Cooke is *A. fumigatus* Fres.

A. nigricans Wreden is *Sterigmatocystis nigra* Van Tieg.

A. repens (Corda) Sacc. is a saprophyte and the same as *A. glaucus* Link.

A. Tokelau Wehmer is a true parasite.

STERIGMATOCYSTIS

S. nigra Van Tieg. is a saprophyte and non-pathogenic for animals.

SACCHAROMYCES

S. anginae Achalme & Troisier and *S. granulatus* Vuillemin & Legrain are the only two species of *Saccharomyces* reported as animal parasites.

SACCHAROMYCOPSIS

S. guttulatus (Robin) Schiönning is normally a saprophyte.

ENDOMYCES

E. albicans Vuillemin produces the disease known as thrush.

FUNGI IMPERFECTI

CRYPTOCOCCUS

There are a large number of cryptococci that have been described, most of them having been obtained from tumors. Their morphology and botanical classification have not been sufficiently established to permit a satisfactory summary at the present time.

OOSPORA AND SPOROTRICHUM

Certain species of *Oospora* and *Sporotrichum* are producers of skin diseases.

GLENOSPORA

G. Graphii (Siebenmann) Vuillemin is evidently a saprophyte.

EXPERIMENTAL DATA

In a preliminary set of isolations a number of yeast cultures were obtained from certain fruits, the sap of trees, and the seeds of various plants growing in the Missouri

Botanical Garden and vicinity. The finding of yeast-like organisms on the seeds of native plants at once suggested the possibility of obtaining yeasts from foreign sources. Four hundred and ninety-three samples of seeds of indigenous plants were received from botanical gardens of Europe, Asia, Africa, Australia, West Indies, Central America, South America, and the Oceanic Islands. A quantity of each kind of seed was separately placed in sterilized test-tubes containing sterilized distilled water. These test-tubes were set aside for twelve hours and then gelatin plates were made by inoculating tubes of sterile beer-wort gelatin with a mm. platinum loop of the water in which the seed had been standing. Only two yeast-like fungi were obtained from these seeds, although a large number of different moulds and bacterial colonies were isolated. The presence of so few yeast-like fungi may have been due to the dry condition which is unfavorable for the survival of many such organisms. Because so few yeasts were obtained from foreign sources, the investigation was later restricted to the material available in and near St. Louis.

Cultures of yeasts were obtained by plating from beer-wort gelatin inoculated with minute quantities of infected fruit juices. Pieces of various fruits and the basal portions of flowers were placed in test-tubes of sterilized water for about twelve hours. Pieces of fruits were also placed in moist chambers for about three days or more. In either case gelatin plates were made by direct inoculation from the moist material. Holes were made in the trunks of a limited number of trees by means of a sterilized auger, one-eighth inch in diameter and extending a short distance beyond the cambium. After three days, samples of the tree sap that had collected in the cavity were transferred to test-tubes of sterilized distilled water by means of a sterilized platinum wire. Gelatin plates were then made directly from the water suspension after it had been standing for about twelve hours. Approximately 850 different sources were examined for yeasts. In all, 180 different strains of fungi were finally obtained from herbaceous seeds, fruits, fruit juices, sap of

trees, and the nectar of flowers. A second and a third series of plates were made from the original colonies, and in most cases this was sufficient for obtaining pure cultures.

Beer-wort gelatin had many advantages over other media, such as beer-wort agar, glucose agar, and potato agar, which are often used for the isolation of these organisms. On agar the growth of bacterial colonies is more rapid than that of the yeast colonies during the first period of incubation; on gelatin the reverse is true, especially with an increase of acidity and a higher percentage of gelatin. The beer-wort gelatin used in these experiments was made by diluting hopped beer-wort with an equal quantity of distilled water, and then adding 12–15 per cent gelatin; the final reaction of the medium was +5 to +7.

The 180 different yeast fungi finally acquired were tested for growth on blood serum medium at blood temperature. It was impracticable to make inoculation experiments on animals with all of these cultures. The blood serum test, therefore, was made with the purpose of eliminating all the cultures that would not grow at 37°C. and presumably under some of the conditions that are to be met with when an organism is introduced into the blood system of higher animals.

The blood serum medium was made by adding one part of nutrient bouillon, obtained from veal, with 1 per cent dextrose, to 3 parts of ox blood serum. The medium was then sterilized at 60 C. for one hour on five successive days and finally coagulated in an inspissator at 75 C. All the tubes were incubated at 37 C. for twenty-four hours in order to eliminate any that were not sterile. The yeast cultures were then transferred to the blood serum medium and kept at 37 C. in a moist chamber for ninety-six hours. The growth appearing after this time was examined microscopically to see if there was any contamination by bacteria. Of the 180 cultures thus tested only twelve strains were obtained which grew under these conditions. These twelve strains included three red, five white, and four black

yeast-like fungi. The sources from which they were derived were as follows:

Culture No. 1. *Torula sp?* from the sap of *Halesia carolina.*

Culture No. 2. *Torula sp?* from the sap of *Pinus sylvestris.*

Culture No. 3. *Torula sp?* from the nectar of *Salvia splendens.*

Culture No. 4. *Torula sp?* from elderberry wine spontaneously fermented.

Culture No. 5. *Torula sp?* from the nectar of *Oenothera sp?*

Culture No. 6. *Torula sp?* from the seeds of *Zea Mays.*

Culture No. 7. *Alternaria sp?* from the fruit of *Ribes Grossularia.*

Culture No. 8. *Alternaria sp?* from the sap of *Pinus austriaca.*

Culture No. 9. *Oospora sp?* from the sap of *Morus alba.*

Culture No. 10. *Alternaria sp?* from the sap of *Populus tremuloides.*

Culture No. 11. *Alternaria sp?* from the seeds of *Sorghum vulgare.*

Culture No. 12. *Alternaria sp?* from the seeds of *Rhus glabra.*

Culture No. 13. A variety of *Saccharomyces cerevisiae* obtained from "Yeast Foam." This culture was used as a control in all the physiological experiments.

Culture 1, Torula sp?—This culture, obtained from the sap of *Halesia carolina,* when grown on beer-wort gelatin and beer-wort agar, develops into spherical colonies of a deep red color, 1–2 mm. in diameter. It may be distinguished from cultures 2 and 3 by its growth on yeast-water agar, on which the colonies attain the size of 2 mm. in diameter—that is, five to ten times the size of the other two

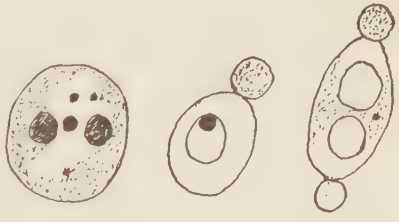


Fig. 1. Culture 1. Cells×2000.

red cultures of *Torula*. It liquefies gelatin rapidly, but culture 2 liquefies gelatin very slowly, and culture 3 not at all. Growth takes place by budding, as in the true yeasts. The cells (fig. 1) are oval or spherical, varying in size from 3–4 × 4–5μ. In sugar nutrient solutions the organism develops rapidly, with the formation of an abundant sediment of yeast cells; but the film, if any, is very thin and made up of colonies loosely connected. In acid yeast-water solution a yellow-brown sediment is formed except in the presence of malic acid in which case the red pigment has practically disappeared, the sediment being almost white. No spores are formed on moist porous plates or on Gorodkowa's test medium, although in many cells there appeared two to four fat globules that are much like endospores in appearance.

Culture 2, Torula sp?—The cells of this strain (fig. 2) vary in size from 3–3.5 × 4–6μ. Growth is by budding from all sides of the mother cell and without the formation of mycelium. Development at 37°C. is more rapid than at room temperature. Cultures grown in yeast water with the addition of saccharose, glucose, levulose, maltose, and lactose, produce a heavy red deposit of yeast cells and a slight ring formation on the surface of the liquid. In yeast water containing 1 per cent of acids—citric, malic, tartaric, and succinic acids—development is as good as in the sugar nutrient solutions. On yeast-water agar the colonies are very small, elliptical or oval in outline, and .2 mm. in diameter. Gelatin is slowly liquefied. No spores are formed.

Fig. 2. Culture 2. Cells×2000.

Culture 3, Torula sp?—This organism, obtained from the nectar of *Salvia splendens*, is brownish red in color. The cells

(figure 3) are oval, 2.8–4×3–6μ. In acid yeast-water solution growth is very rapid; and in the presence of lactic and citric acids, only isolated colonies are formed on the bottom of the culture flask. In sugar nutrient solutions it produces a sediment of yeast cells and a thin film on the surface of the liquid. No spores are formed.

Fig. 3. Culture 3. Cells×2000.

Culture 4, Torula sp?—This white species of *Torula,* obtained from elderberry wine spontaneously fermented, develops in the same manner as the cultivated yeasts. The cells (fig. 4) are oval, 3–4 × 4–5μ in diameter. Cultures in yeast water containing saccharose, dextrose, levulose, maltose,

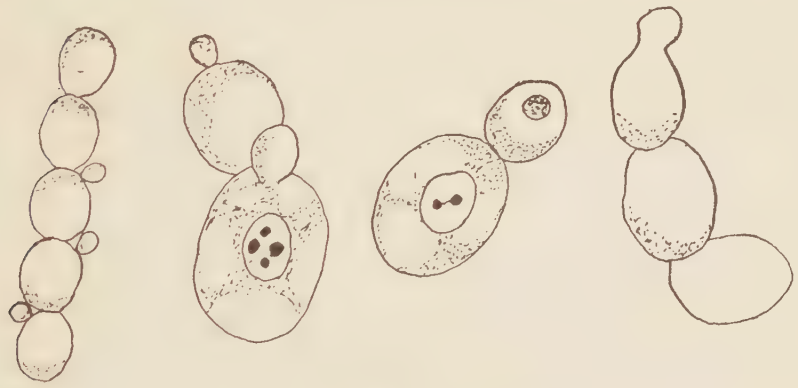


Fig. 4. Culture 4. Cells×2000.

and lactose, develop rapidly, with a sediment of yeast cells and the formation of a thin film on the surface of the culture liquid. In yeast water containing succinic, citric, or acetic acids, the film on the surface of the culture liquid is white, opaque, and wrinkled. In the presence of tartaric and

malic acids the separate colonies are connected into a net-like film. Gelatin is not liquefied, and no spores are formed.

Culture 5, Torula sp?—The cells of this species (fig. 5), obtained from the nectar of *Oenothera sp.?*, are oval to elliptical, 2–2.5 × 4–5μ. On beer-wort agar and gelatin the colonies are small, white, and spherical. In sugar nutrient solutions and in yeast water containing citric, malic, or lactic acids, there is a considerable sediment of yeast cells and a thin film on the surface of the culture liquid. In yeast water containing tartaric acid the colonies remain more or less distinctly formed on the bottom of the culture flask. No spores are produced, and gelatin is not liquefied.

Fig. 5. Culture 5. Cells×2000.

Culture 6, Torula sp?—The colonies of this species of *Torula*, obtained from the seeds of *Zea Mays*, may be distinguished from cultures 4 and 5 by the growth appearance on agar and gelatin. The margin of the colonies is irregular and extends radially from the center of growth. The cells (fig. 6) are smaller, being 1.5–2.5 × 2–3.5μ. Multiplication is by budding, more particularly at the ends of the mother cells. In nutrient solutions containing galactose and levulose, development takes place rapidly, with the formation of a sediment of yeast cells and a very dense wrinkled film on the surface of the liquid. In nutrient solutions containing maltose and lactose, the film is

Fig. 6. Culture 6. Cells×2000.

made up of a network of distinct colonies, but in the presence of saccharose the film is slimy and stringy in appearance. Dextrose and levulose are fermented. Gelatin is not liquefied, and spores are not formed.

Culture 7, Alternaria sp.?—Colonies of this organism, obtained from the fruit of *Ribes Grossularia,* on gelatin or agar plates, appear much like the colonies of wild yeasts. At first they are made up of budding cells; later a few radiating strands of mycelium appear, with budding conidia at or near the cross walls. The culture soon becomes black from the formation of chlamydospores. The growth on

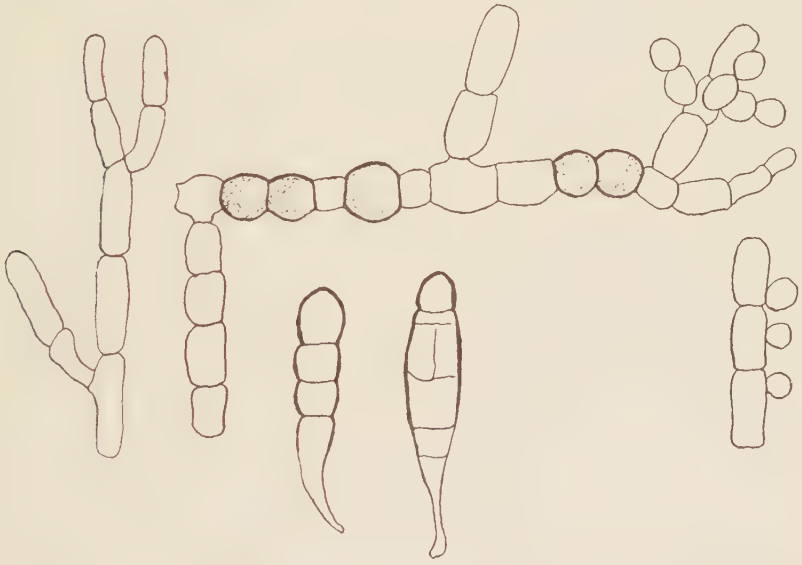


Fig. 7. Culture 7. Vegetative cells, conidia, chlamydospores, and muriform spores.

agar after seven days, results in the appearance of four distinct regions to each colony. The central part is black and shiny with a slightly wrinkled surface. About this area are three zones concentrically arranged and of a very dark green color, the terminal margin being made up of a filamentous growth.

In nutrient sugar solutions, the film is at first white then black. Dextrose and saccharose are fermented. In yeast

water containing organic acids, there is a sediment of yeast cells and a film of anastomosing colonies. Gelatin is liquefied. The cells (fig. 7) vary in size from 6–8 × 8–10μ. Besides the single-celled chlamydospores, there are occasionally many-celled spores borne on short conidiophores. The septa in the spore occur both at right angles and parallel to the long axis and are muriform.

Culture 8, Alternaria sp?—The colonies of this culture are at first made up of a central mass of yeast cells with my-

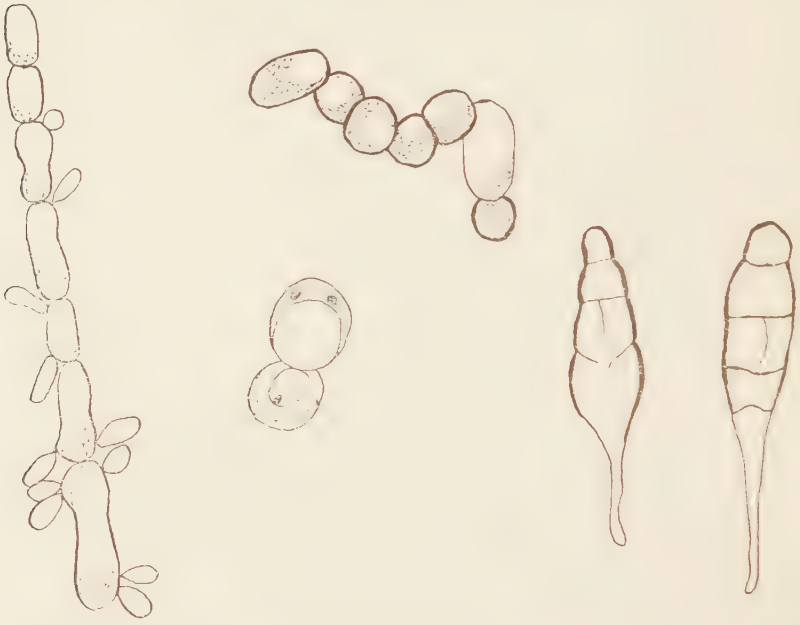


Fig. 8. Culture 8. Vegetative cells, conidia, chlamydospores, and muriform spores.

celium extending radially from the center. Budding conidia are rapidly formed at regular intervals on this mycelium. The cells (fig. 8) vary in size from 3–6 × 4–9μ. After seven days' growth on agar, the colonies may be separated into a central flat disc and several distinct zones, these zones gradually changing from a dark green to a black color. In sugar nutrient solutions there is a rapid growth and a very thick, slimy, greenish black film. Dextrose, saccharose, and

maltose are fermented. In yeast water containing organic acids, growth is as rapid as in the sugar nutrient solutions; but instead of forming a film, the growth on the surface is limited to the margin along the side of the culture flask. The cells vary in size from 2 × 10–25μ or 3 × 7–8μ. Gelatin is liquefied. Chlamydospores and muriform many-celled spores occur in acid yeast-water solution.

Culture 9, Oospora sp?—The colonies of this organism appear much like certain white yeasts. They are circular in outline and have a more or less wrinkled surface. Growth of this organism does not take place by budding; but the mycelium, which is dichotomously branched, predominates

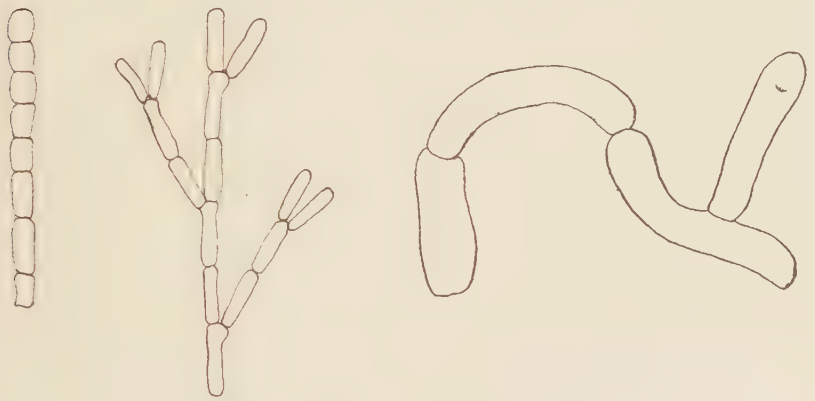


Fig. 9. Culture 9. Vegetative cells.

in all media. The cells (fig. 9) are elongated, 2–2.5 × 12–15μ, or short and rectangular, 3–4×4–6μ. In yeast water containing organic acids, certain of the cells may become quite large and sickle-shaped, 4–5×20–30μ. No chlamydospores or conidia are found in any of the cultures. When grown in Raulin's nutrient sugar solutions the liquid becomes bright red in color. This characteristic easily distinguishes this organism from the other cultures with mycelial growth. Gelatin is liquefied.

Culture 10, Alternaria sp?—This organism growing on agar forms a membrane of yeast cells and mycelium of a flesh-pink color. The yeast cells (fig. 10) vary in size from

4–8 × 5–8μ. The culture does not become dark in any media and rarely forms chlamydospores. In yeast water containing organic acids only a few chlamydospores are found among the cells on the surface of the liquid. In nutrient sugar solutions and in yeast water containing organic acids the

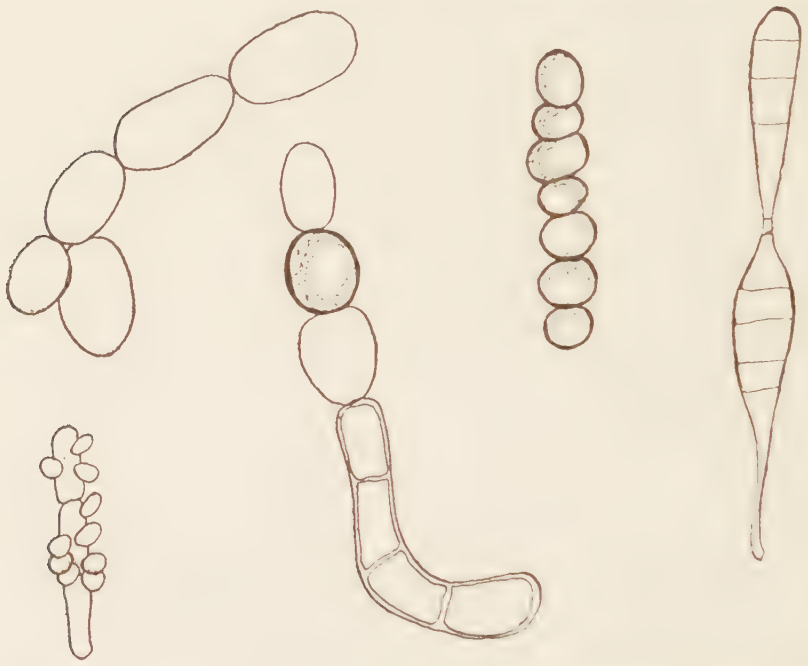


Fig. 10. Culture 10. Vegetative cells, conidia, chlamydospores, and muriform spores.

vegetative growth results in the formation of a white, glistening mass of fungous elements that cannot be separated easily. Only a few muriform many-celled spores are found, which indicates its being a species of *Alternaria* that does not readily form spores in culture.

Culture 11, Alternaria sp?—This organism liquefies gelatin more rapidly and becomes black—due to the formation of chlamydospores—more quickly than any of the fungi previously described. On gelatin or agar it first appears in irregular yeast-like colonies. The budding conidia develop rapidly; and if the colonies on the surface of the media

are crowded, only yeast cells are formed. Saccharose and maltose are fermented. In yeast water containing citric, tartaric, or succinic acids, the sediment is made up of yeast cells, whereas the black, leathery film is composed of mycelia and chlamydospores. The cells (fig. 11) vary in size from 4–6 × 10–12μ or 2 × 10–50μ. The many-celled muriform spores are found in cultures grown in acid yeast-water solutions.

Culture 12, Alternaria sp?—This fungus is differentiated in part from the other black yeast-like fungi by the late ap-

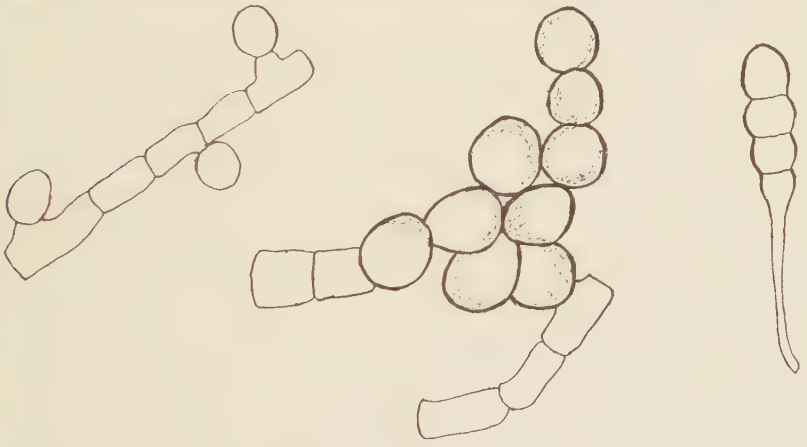


Fig. 11. Culture 11. Vegetative cells, chlamydospores, and muriform spores.

pearance of chlamydospores and the predominance of yeast cells. In early cultures on agar the colonies are yeast-like in appearance, and the mycelium starts to develop only after the medium has become less moist. In nutrient solutions containing sugars the growth is very rapid, and a ring of colonies appears on the surface. In yeast water containing organic acids there is a sediment of yeast cells, or the growth is limited to isolated colonies on the bottom of the flask. The ring appearing on the surface of the liquid is white in color except in the presence of lactic acid, in which case it is black. This fungus, a species of *Alternaria,* has dark chlamydospores and many-celled muriform spores. The cells (fig. 12) vary in size from 3–4 × 5–50μ. Gelatin is

rapidly liquefied. Saccharose, dextrose, levulose, and maltose are fermented.

Culture 13, Saccharomyces cerevisiae.—This yeast, obtained from "Yeast Foam," has spherical cells (fig. 13) varying in size from 5 to 9μ in diameter. Growth takes place by budding from all sides of the mother cell. In nutrient sugar solutions the organism forms a sediment of yeast cells and a thin film only in the presence of glucose. In yeast water containing organic acids, the sediment of yeast cells has a flocculent appearance. Saccharose, dextrose, levulose, and

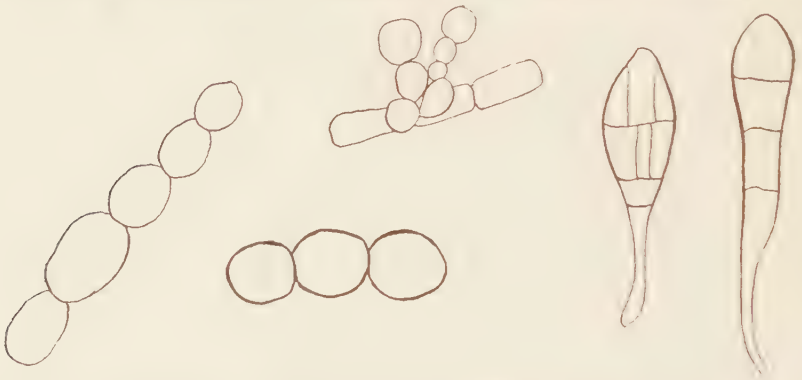


Fig. 12. Culture 12. Vegetative cells, conidia, chlamydospores, and muriform many-celled spores.

maltose are fermented, with the formation of alcohol and carbon dioxide. Spores are formed on moist porous plates, on Gorodkowa's test medium, and on yeast-water agar. On the latter medium, after a growth of ten days, 30–40 per cent of the yeast cells have formed endospores. The number of ascospores in the asci varies from 1 to 4, and they vary in size from 2.5 to 4μ in diameter. Upon germination the spores enlarge and are set free from the spore case and then develop separately, or the spores may fuse as they become larger, the spore case becoming thinner at the same time, which results in a very large cell that develops by budding. Sometimes the ascospores start to germinate before they are set free from the ascus.

The reaction of the thirteen organisms was tested in nutrient solutions of saccharose, dextrose, levulose, and mal-

tose. The sugar nutrient solutions contained 1 per cent peptone, .3 per cent monopotassium phosphate, and .02 per cent magnesium sulphate. The concentration of the sugar was 5 per cent saccharose, 5 per cent dextrose, 1 per cent levulose, and 1 per cent maltose, respectively.

For the determination of alcohol formation, 100 cc. of the sugar nutrient solutions were placed in 125-cc. Erlenmeyer

Fig. 13. Culture 13. Vegetative cells, asci with ascospores, and spores during germination.

flasks, and after sterilization each was inoculated with a pure culture of one of the thirteen different strains and incubated at room temperature for thirty days. Immediately after the inoculation of the nutrient solutions the cotton plugs in the culture flasks were replaced by one-holed rubber stoppers, through which passed a piece of small glass tubing with a small cotton plug. This precaution was taken to prevent excessive evaporation. After the incubation at room temperature for thirty days, the nutrient solutions were neutralized with normal caustic soda and made up to the

original volume with distilled water. The loss by evaporation did not exceed .3 cc. in any case. Fifty cc. were then distilled off, and the amount of alcohol present determined with a pycnometer. The presence of alcohol was confirmed in each case by means of the iodoform test as used by Will ('10) in his investigation on certain species of *Mycoderma*.

TABLE I

SHOWING THE PERCENTAGE, BY VOLUME, OF ALCOHOL PRODUCED BY THE THIRTEEN DIFFERENT CULTURES AFTER INCUBATION AT ROOM TEMPERATURE FOR THIRTY DAYS

Culture no.	Saccharose	Iodoform test	Dextrose	Iodoform test	Levulose	Iodoform test	Maltose	Iodoform test
1	.10	—*	.10	—	.10	—	.30	—
2	.05	—	.05	—	.10	—	.30	—
3	.00	—	.10	—	.10	—	.00	—
4	.15	—	.00	—	.10	—	.20	—
5	.00	—	.00	—	.10	—	.05	—
6	.00	—	.85	+	.30	+	.10	—
7	.95	+	.65	+	.15	—	.25	—
8	1.20	+	.45	+	.10	—	.45	+
9	.00	—	.00	—	.05	—	.20	—
10	.10	—	.10	—	.05	—	.00	—
11	.95	+	.35	—	.15	—	.55	+
12	.80	+	1.00	+	.50	+	.75	+
13	5.35	+	5.00	+	.70	+	.85	+
Control (without organism)	.00	—	.00	—	.00	—	.00	—

*The sign + indicates that the iodoform test for alcohol was positive, with the presence of iodoform crystals.

The results, as indicated by table 1, show that very little alcohol, if any, is formed by the various cultures with the exception of culture 13 (*Saccharomyces cerevisiae*), which was used as a control. Only one culture of *Torula*, culture 6, produced alcohol by the fermentation of dextrose and levulose. Four of the black yeast-like fungi-cultures, 7, 8, 11, and 12, produced only small quantities of alcohol.

The reaction of the thirteen different cultures was tested in yeast water containing organic acids. Seventy-five grams of press-yeast were ground up with enough distilled water to form a thin paste. More distilled water was then added

to make up the volume to one liter. This yeast suspension was then heated in an Arnold sterilizer at 100°C. for one hour. After most of the yeast cells had settled to the bottom of the flask, the supernatant liquid was decanted and filtered through hard filter paper. This filtrate was then run through a Berkfeld cylinder to remove all yeast cells. The acid nutrient solutions were made from this last filtrate by the addition of 1 per cent citric, 1 per cent lactic, 1 per cent malic, 1 per cent succinic, 1 per cent tartaric, and .5 per cent acetic acid.

For the acid reaction 50 cc. of the acid nutrient solutions in 100-cc. Erlenmeyer flasks were sterilized, and then each was inoculated with a pure culture from one of the thirteen fungi. After incubation for thirty days at room temperature, the solutions were made up to the original volume with distilled water. A 10-cc. portion was then titrated with N/10 caustic soda, phenylphthalein and litmus being separately used as indicators. The results given in table II are in terms of cubic centimeters of N/10 caustic soda required to neutralize 10 cc. of the culture solutions.

TABLE II

SHOWING THE FINAL ACID REACTION AND THE CHANGE IN REACTION THAT HAD TAKEN PLACE AFTER THE CULTURES WERE INCUBATED AT ROOM TEMPERATURE FOR THIRTY DAYS

Culture no.	Acid	Phenylphthalein as indicator	Difference	Litmus as indicator	Difference
Control	Acetic	6.3*	—	5.6	—
	Citric	6.55	—	5.7	—
	Lactic	4.5	—	3.8	—
	Malic	6.15	—	5.45	—
	Succinic	6.5	—	5.9	—
	Tartaric	6.0	—	5.5	—
1	Acetic	6.5	+ .2	5.7	+ .1
	Citric	5.5	—6.0	—.3	—6.0
	Lactic	3.0	—1.5	2.3	—1.5
	Malic	3.5	—2.65	2.8	—2.65
	Succinic	2.9	—3.6	2.3	—3.6
	Tartaric	5.1	— .9	4.5	—1.0
2	Acetic	6.7	+ .4	6.1	+ .5
	Citric	.3	—6.25	—.3	—6.0
	Lactic	.25	—4.25	—.5	—4.3
	Malic	.3	—5.85	—.3	—5.75
	Succinic	.3	—6.2	—.5	—6.4
	Tartaric	3.8	—2.2	3.3	—2.2
3	Acetic	6.3	.0	5.7	+ .1
	Citric	4.1	—2.45	3.3	—2.4
	Lactic	3.4	—1.1	2.7	—1.1
	Malic	.7	—5.45	.2	—5.25
	Succinic	.5	—6.0	—.4	—6.3
	Tartaric	5.2	— .8	4.5	—1.0
4	Acetic	.1	—6.2	—.5	—6.1
	Citric	.45	—6.1	—.3	—6.0
	Lactic	.4	—4.1	—.3	—4.1
	Malic	.35	—5.8	—.3	—5.75
	Succinic	.3	—6.2	—.3	—6.2
	Tartaric	6.2	+ .2	5.5	.0
5	Acetic	6.65	— .35	5.9	+ .3
	Citric	.9	—5.65	.2	—5.5
	Malic	2.65	—1.85	2.0	—1.8
	Lactic	.3	—5.85	—.3	—5.75
	Succinic	.4	—6.1	—.3	—6.2
	Tartaric	5.7	— .3	5.0	— .5

*The results are given in terms of cc. N/10 caustic soda required to neutralize 10 cc. of the culture solutions; and the change in reaction, whether an increase or decrease, is indicated in terms of cc. N/10 caustic soda per 10 cc. of the culture solution.

TABLE II. (Continued)

Culture no.	Acid	Phenylphthalein as indicator	Difference	Litmus as indicator	Difference
6	Acetic	6.65	+ .35	5.8	+ .2
	Citric	.3	—6.25	— .4	—6.1
	Lactic	.7	—3.85	.2	—3.6
	Malic	.2	—5.95	— .4	—5.85
	Succinic	.4	—6.1	— .2	—6.1
	Tartaric	5.4	— .6	4.9	— .6
7	Acetic	6.9	+ .6	6.1	+ .5
	Citric	.4	—6.15	— .3	—6.0
	Lactic	1.6	—2.9	1.0	—2.8
	Malic	.1	—6.05	— .5	—5.95
	Succinic	.0	—6.5	— .6	—6.5
	Tartaric	.5	—5.5	— .3	—5.8
8	Acetic	7.7	+1.4	6.8	+1.2
	Citric	.3	—6.25	— .4	—6.1
	Lactic	1.6	—2.9	1.2	—2.6
	Malic	.2	—5.95	— .5	—5.95
	Succinic	.0	—6.5	— .6	—6.5
	Tartaric	.3	—5.7	— .3	—5.8
9	Acetic	6.9	+ .6	6.0	+ .4
	Citric	6.8	+ .25	6.1	+ .4
	Lactic	4.6	+ .1	4.1	+ .3
	Malic	6.0	+ .15	5.3	+ .15
	Succinic	6.3	— .2	5.4	— .5
	Tartaric	7.5	+1.5	7.0	+ .5
10	Acetic	7.6	+1.3	7.0	+1.4
	Citric	5.3	—1.25	4.5	—1.2
	Lactic	3.1	—1.4	2.4	—1.4
	Malic	3.3	—2.85	2.5	—2.95
	Succinic	.4	—6.1	— .3	—6.2
	Tartaric	6.0	0.0	5.6	+ .1
11	Acetic	6.9	+ .6	6.2	+ .6
	Citric	.2	—6.35	— .6	—6.3
	Lactic	1.3	—3.2	.7	—3.1
	Malic	.2	—5.95	— .4	—5.85
	Succinic	.0	—6.5	— .6	—6.5
	Tartaric	.4	—5.6	— .2	—5.7
12	Acetic	7.6	+1.3	6.8	+1.2
	Citric	3.8	—2.75	3.0	—2.7
	Lactic	3.1	—1.4	2.5	—1.3
	Malic	.5	—5.65	— .1	—5.55
	Succinic	.2	—6.3	— .4	—6.3
	Tartaric	5.3	— .7	4.8	— .7
13	Acetic	6.6	+ .3	5.8	+ .2
	Citric	5.5	+1.05	4.7	+1.0
	Lactic	2.3	—2.2	1.8	—2.0
	Malic	4.4	—1.75	3.7	—1.75
	Succinic	4.2	—2.3	3.8	—2.1
	Tartaric	6.4	+ .4	5.8	+ .3

TABLE III

SHOWING THE CHANGE IN ACID REACTION BROUGHT ABOUT BY THE THIRTEEN CULTURES DURING THE INCUBATION AT ROOM TEMPERATURE FOR THIRTY DAYS

(Results are the averages of the two titrations given in table II)

Culture no.	Acetic	Citric	Lactic	Malic	Succinic	Tartaric
1	+ .15*	—6.0	—1.5	—2.65	—3.6	— .95
2	+ .45	—6.1	—4.3	—5.8	—6.3	—2.2
3	.0	—2.4	—1.1	—5.35	—6.15	— .9
4	—6.15	—6.05	—4.1	—5.8	—6.2	+ .1
5	+ .3	—5.6	—1.8	—5.8	—6.15	— .4
6	+ .25	—6.2	—3.7	—5.9	—6.1	— .6
7	+ .55	—6.1	—2.85	—6.0	—6.5	—5.65
8	+1.3	—6.15	—2.75	—5.95	—6.5	—5.65
9	+ .5	+ .3	+ .2	+ .15	— .35	+1.5
10	+1.35	—1.2	—1.4	—2.9	—6.15	0.0
11	+ .6	—6.3	—3.15	—5.9	—6.5	—5.65
12	+1.25	—2.7	—1.35	—5.6	—6.3	— .7
13	+ .25	+1.0	—2.1	—1.75	—2.2	+3.5

*In terms of N/10 caustic soda per 10 cc. culture solution.

The results, as indicated by tables II and III, show that all the cultures produce a change in the reaction of the acid yeast-water solutions after incubation at room temperature for thirty days. There is a decrease in the acidity of all the acid nutrient solutions except in the presence of acetic acid, in which case a marked decrease in acidity was brought about only by culture 4. In the case of culture 9, only a slight change of acidity was found in any of the acid nutrient solutions.

ANIMAL EXPERIMENTS

The experiments on animals were made in the laboratory of the pathological department of the Washington University Medical School, under the direction of Dr. E. L. Opie and Dr. W. S. Thomas. Rabbits and guinea-pigs were inoculated with suspensions of the different yeast-like fungi, with the exception of cultures 3 and 13, either from cultures grown in Hansen's solution for 12 hours, or from 48-hour cultures grown on agar and suspended in Ringer's physiological salt solution.[1] In each case 2 cc. were injected into the

[1]Ringer's solution contains the following:
Sodium chloride..... .7 per cent Calcium chloride..... .028 per cent
Potassium chloride.... .035 per cent Sodium carbonate..... .003 per cent

marginal ear vein of rabbits, or 1 cc. intraperitoneally or subcutaneously in the guinea-pigs. All injections were made under aseptic conditions with sterilized instruments.

The animals that died were carefully examined for lesions or abnormalities, the autopsy being carried out with aseptic precautions with sterilized instruments. At the same time a sample of blood was taken from the right auricle of the heart, with a sterilized platinum loop, and transferred to a tube containing sterilized beer-wort. All the principal organs were removed to sterilized Petri dishes, and then small pieces of the liver, lungs, spleen, kidneys, and intestines were placed in tubes of sterilized beer-wort. These tubes were then incubated at 28°C. for seventy-two hours, but were kept under observation for over ten days, and then gelatin plates made from them.

Where the organisms had been inoculated into beer-wort and the same procedure used as for the animal tissues, pure cultures were again easily obtained on gelatin plates with all the eleven strains used.

At the same time pieces of the different organs were fixed in Bouin's or Gilson's fluid, imbedded in paraffin, sectioned, and stained with saffranin and methyl blue, or with Delafield's hematoxylin and eosin, or according to the method used by Pianeze ('96) for the staining of carcinoma tissue.

TABLE IV

RESULTS OF ANIMAL EXPERIMENTS

Experiment number	Animal number	Kind of animal	Sex	Culture number	Kind of culture	Kind of injection	Days until death	Cause of death	Lesions	Source of organism	Stained preparations
1	1	G-p*	M*	1	R*	P*	....	Killed	.....	None	Negative
	2	r*	M	2	H*	V*	56	Unknown	White spots on liver	Intestines	Lung air spaces condensed
2	3	G-p	M	2	H	S*	35	Unknown	None	None	Negative
	4	G-p	M	2	H	P	49	Unknown	None	None	Negative
	5	G-p	M	2	R	P	....	Killed	None	None	Negative
	6	G-p	F*	4	H	S	....	Killed	None	None	Negative
	7	G-p	M	4	H	P	7	Unknown	None	Intestines	Lung air spaces condensed
3	8	G-p	M	4	H	P	17	Unknown	None	None	Negative
	9	G-p	F	4	R	P	....	Killed	None	None	Negative
	10	G-p	F	4	R	P	....	Killed	None	None	Negative
	11	r	M	5	H	V	1½	Unknown	None	None	Negative
	12	r	M	5	R	V	....	Killed	None	None	Negative
4	13	r	M	5	R	V	....	Killed	None	None	Negative
	14	G-p	M	5	H	S	....	Killed	None	None	Negative
	15	G-p	F	5	H	P	60	Unknown	None	None	Negative
	16	G-p	M	6	H	S	....	Unknown	None	None	Negative
5	17	G-p	M	6	H	P	16	Unknown	None	None	Negative
	18	r	F	6	H	V	....	Killed	None	None	Negative
6	19	G-p	M	7	R	P	20	Unknown	None	None	Negative
	20	r	M	7	b-w*	V	....	.....	.....	.....	.....
7	21	G-p	M	8	R	P	20	Unknown	None	None	Negative
	22	r	M	8	b-w	V	....	.....	.....	.....	.....
	23	r	M	9	H	V	60	Unknown	White spots on liver	None	Negative
8	24	G-p	F	9	H	P	....	Unknown	None	None	Negative
	25	G-p	M	9	R	P	....	Unknown	None	None	Negative
9	26	G-p	M	10	R	P	10	Unknown	None	None	Negative
	28	r	M	10	b-w	V	....	.....	.....	.....	.....
	27	G-p	M	11	R	P	20	Unknown	None	None	Negative
	29	r	F	12	H	V	....	Killed	None	None	Negative
10	30	G-p	M	12	H	S	....	Killed	None	None	Negative
	31	G-p	M	12	H	P	20	Unknown	None	Intestines and lungs	Lung air spaces condensed
	32	G-p	M	12	R	P	....	Killed	None	None	Negative
11	33	G-p	M	12	b-w	P	3	Unknown	None	None	Negative
	34	r	M	12	b-w	V	.....	.....	.....	.....	.....

*G-p represents guinea-pig; r, rabbit; M, male; F, female; H, suspension in Hansen's solution; R, suspension in Ringer's solution; P, intraperitoneal; S, subcutaneous; V, intravenous; b-w, sterilized in beer-wort.

TABLE V

SHOWING THE WEIGHT IN GRAMS OF THE ANIMALS WEEK BY WEEK*

Animal no.	Initial wt.	Weight at end of the following periods:								Remarks
		1st wk.	2nd wk.	3d wk.	4th wk.	5th wk.	6th wk.	7th wk.	8th wk.	
1	*555	500	475	531	520	550	535	....	....	570 gms. after 5 months.
2	2450	2400	2370	2300	2280	2170	2100	2010	1810	Died 9 days after 8th wk.
3	....	375	333	320	310	275	....	....	....	Died after 4 wks. 5 days.
4	....	435	420	410	449	402	402	340	....	Died after 6 wks. 5 days.
5	570	490	470	520	495	....	....	....	....	515 gms. after 4 months.
6	385	365	370	370	405	400	400	410	380	450 gms. after 4 months.
7	390	290	....	....	....	....	....	....	....	Died after 7 days.
8	535	475	....	435	....	....	....	....	....	Died after 2 wks. 3 days.
9	560	480	515	....	485	560	....	615	....	620 gms. after 4 months.
10	570	495	500	....	475	475	....	515	....	520 gms. after 4 months.
11	2050	2030	....	....	....	....	....	....	....	Died after 9 days.
12	2600	2400	....	2300	2240	....	....	2110	....	Killed after 2 months.
13	1700	1550	....	1635	1490	....	....	1745	....	Killed after 2 months.
14	395	370	380	375	405	380	385	395	350	400 gms. after 3 months.
15	375	350	372	372	400	380	355	380	317	Died after 2 months.
16	375	355	345	335	365	355	355	365	375	400 gms. after 4 months.
17	265	240	240	235	240	225	220	....	....	Died after 5 wks. 5 days.
18	1670	1575	1690	1620	1750	1700	1540	1680	1820	1690 gms. after 4 months.
19	555	510	....	405	....	....	....	....	....	Died after 2 wks. 5 days.
20	660	....	....	....	....	....	....	....	....	Living.
21	530	475	....	395	....	....	....	....	....	Died after 2 wks. 5 days.
22	780	....	....	....	....	....	....	....	....	Living.
23	1350	1400	1340	1390	1430	1430	1430	1460	1420	1365 gms. after 9 wks.
24	....	382	380	325	375	375	390	410	415	Killed after 2 months.
25	500	440	....	420	460	....	435	....	420	Killed after 2 months.
26	465	....	395	....	....	....	....	....	....	Died after 10 days.
27	470	445	....	400	....	....	....	....	....	Died after 20 days.
28	870	....	....	....	....	....	....	....	....	Living.
29	1300	1280	1240	1295	1250	1250	1385	1350	1415	Killed after 2 months.
30	....	345	325	310	338	342	359	325	345	Killed after 2 months.
31	....	311	300	280	....	....	....	....	....	Died after 20 days.
32	470	....	385	420	415	....	455	450	....	535 gms. after 4 months.
33	410	360	....	....	....	....	....	....	....	Died after 3 days.
34	920	....	....	....	....	....	....	....	....	Living.

*Each animal was weighed once a week from the time of inoculation to the time of death.

The results of experiment 1 were negative.

In experiment 2 animal No. 2, white spots were found on the liver. These lesions were not caused by the organism injected, for inoculations were taken directly from these areas but no fungous culture was obtained. Rabbits are frequently infected by coccidia, and it is probable that they were the cause of the lesions in this animal. Stained

preparations revealed a condensation of the air spaces of the lungs. There were no organisms present and this condition was probably due to post-mortem changes such as oedema.

In experiment 3 animal No. 7 died after seven days, and the autopsy revealed the intestines very much inflamed. The organism was isolated from the intestines, and stained preparations showed abnormalities in the condensation of air spaces in the lungs. A repetition of this experiment gave negative results.

In experiment 4 animal No. 11 died in less than two days from causes that could not be determined. The death of this animal may have been due to the fact that phagocytosis was not sufficiently active, since a repetition of the same experiment gave negative results.

In experiment 5 the results were negative.

In experiment 6 animal No. 19 died after twenty days without evidence of lesions. To test out the production of toxin by culture No. 7, 1 cc. of a four-day culture in beer-wort after sterilization was injected intravenously into a 660-gram rabbit, but the results were negative.

In experiment 7 animal No. 21 died after twenty days from unknown causes. The condensation of air spaces found in the lungs was probably due to post-mortem changes. Animal No. 22, a 780-gram rabbit, was subjected to a 1-cc. sterilized injection of a four-day culture of organism No. 8, with negative results.

In experiment 8 animal No. 23 died after two months without evidence of lesions other than white spots on the liver which were presumably due to coccidia, since no fungous culture was obtained from this lesion.

In experiment 9 animal No. 26 died after ten days from unknown causes. Intravenous injection in an 870-gram rabbit of a 1-cc. four-day sterilized culture grown in beer-wort, gave negative results.

In experiment 10 animal No. 27 died after twenty days without evidence of lesions or the presence of fungi in the various organs.

In experiment 10 animal No. 31 died after twenty days. The organism injected was again isolated from the intestines and the lungs. The condensation of air spaces in the lungs of this animal was probably due to post-mortem changes. A repetition of this experiment gave negative results, as shown by animal No. 32 which lived four months without evidence of any injurious effects due to an organism. Animal No. 33 received a 1-cc. injection of a two-day sterilized culture of organism No. 12, grown in beer-wort. This animal died in three days. However, a 2-cc. intravenous injection of a two-day sterilized culture of organism No. 12, grown in beer-wort, gave negative results.

All the remaining twenty-four animals inoculated gave negative results, in that no evidence was found of an injurious effect due to the cultures injected.

DISCUSSION

There has been a diversity of opinion in regard to the importance of fungi as agents in the production of infectious diseases. More recent investigations indicate that fungi are of secondary importance in the formation of lesions in animal bodies, and usually appear secondarily in infected tissues. On the other hand, certain species of fungi are to be considered of primary importance in those cases in which they prove toxic to animals if consumed in large quantities on infected foods.

It is easy to recognize that the parasitic fungus cannot prosper with the same degree of success on all animal species. Mucor and Aspergillus pneumonomycoses, observed frequently in birds, is rarely found in other animals. Certain varieties of *Sporotrichum (Microsporon)* which occur on infants, seem to grow with difficulty on animals. Certain varieties of *Oospora* (*Trichophyton*) are common to man and other animals, whereas still other varieties of *Oospora* appear only on man. The changes brought about by the disease-producing organisms in the body are quite varied, differing quite as much as the morphological and cultural characters of the organism when grown outside the body.

In close connection with the anatomical changes produced in the body a study should be made of the physiological relations of host and parasite, more particularly the conditions which predispose the body to attack. Sticker ('00) observed that mycosis in man may be of sporadic or of endemic origin. In the former case weakened individuals suffering from other diseases are attacked. Out of thirty-nine cases of mycosis only five occurred in persons supposedly in good health. The endemic disease appears in consequence of the patient's vocation: for example, the pigeon caretaker, hair-dressers in Paris, and the sponge purifiers.

The diseases produced by fungi, in proportion to the wide distribution of parasitic species, are of rare occurrence in man. Siebenmann, who investigated the distribution of *Aspergillus fumigatus* from the literature on otomycosis, discovered that, while it appeared in all parts of Europe and America, it was most abundant in India, its frequency depending on the time of the year.

The experimental results with injections of certain species of the *Phycomycetes* have been mostly negative. All authentic instances of subcutaneous injections have given negative results, whereas only a few species of the *Phycomycetes* produce death in animals by intraperitoneal or intravenous injections. The resulting lesions in the rabbits and guinea-pigs vary with the manner of injection, the kidneys and mesenteric glands being regularly altered. An injection of a 2-cc. spore-suspension of a non toxic fungus (*Sterigmatocystis nigra*) will result in the animal's losing 10 to 25 per cent in weight during the first three or four days after the injection; after this period the animal rapidly regains its original weight. If the amount of injection is increased, the animal will die from mechanical causes in about eight days. Sections of the kidneys show that the spores have collected in the glomeruli, where some of the spores germinate but no multiplication of cells takes place. The heart and blood remain sterile.

Ballin ('08) subjected animals to five-day cultures of certain moulds. He then killed the animals after a few hours

and investigated the lungs microscopically. According to this author, if guinea-pigs are allowed to breathe the spores of *Aspergillus fumigatus* grown on agar plates, they die within seven or eight hours by asphyxia. Upon examination of the lungs of the dead animals, he had no difficulty in finding the spores in hemorrhagic colonies which permeated the lungs. The same result was obtained with cultures of *Sterigmatocystis nigra*. The germination of the spores takes place in the alveolar septa between the alveoli, and then by means of pressure the germinating spores break through the cell walls and enter the alveoli.

Fungous infectious agents are not absolutely deprived of the power to secrete toxic substances, although this toxicity does not seem to be as evident in them as in the bacteria. Lucet was among the first to mention the existence of a thermolabile toxic substance in cultures of *Aspergillus fumigatus*. The earlier investigators assert that the intensity of the toxic action of certain fungi is proportional to the quantity of the fungous spores injected, and in this manner the higher fungi differ from pathogenic bacteria, in which the resultant intensity of toxic action is to a large extent independent of the number of bacteria injected into the animal.

Ceni ('07) found that the toxic action of an alcoholic or ether extraction from cultures of *Aspergillus fumigatus* was of a specific character. He isolated a culture of *Aspergillus* from the atmosphere in the home of a family affected with chronic pellagra, and obtained a water-soluble toxin from the cultures of this fungus. He also isolated two toxic varieties of *Penicillium* from corn, the toxic substance from one variety producing neuromuscular condensations in animals, whereas the toxic substance in the other produced nervous depression. Bodin and Gautier ('06) also found that this toxin was not destroyed by heating to 120°C. for thirty minutes. Otto ('07) obtained an alcoholic extract from five strains of *Aspergillus fumigatus* which was toxic for animals either by intraperitoneal injection, or as an emulsion if washed into the stomach by means of a probe. Not only

the spores but also the mycelium contained substances of intensive poison. Sturli ('10) extracted a toxin from cultures of *Penicillium glaucum*, which was neither a phenol, an acid, or an alkaloid.

Blakeslee and Gartner ('13) found that the "presssaft" from the aërial filaments of *Rhizopus nigricans* caused almost instant death when injected intravenously into rabbits. Several other species of *Mucorineae* were tested but with negative results. A solution containing the water-soluble substance extracted from .045 grams of the dry fungus, when injected intravenously, is sufficient to kill a 1.35-kilogram rabbit in less than two minutes. The poison from *Rhizopus* appears to be 5.5 times that of the tubercle bacillus, 15 times that obtained from edestin, and 45 times that of penicillic acid. *Rhizopus nigricans* is widely distributed, and is almost certain to appear as a spontaneous infection on bread and similar substrata rich in carbohydrates whenever the proper temperature and moisture requirements are observed. Blakeslee and Gartner point the possible relation of this fungus to diseases of unknown origin, such as pellagra, horse disease, and the cornstalk disease of the Middle West, all of which have been attributed to infected food.

Mohler ('14), in a review of the investigations on cerebrospinal meningitis (forage-poisoning), emphasized the widely accepted theory that this disease may be due to fungi on the feed. While most investigators have obtained negative results, Mays reported that a colt fed experimentally upon some of the mouldy corn which was held responsible for the serious outbreak in Kansas in 1890, developed the disease on the twenty-sixth day. Again, the Kansas outbreak in 1906 was said by Haslam to have been caused by the consumption of immature ears of corn infected by moulds, although the exact mould was not determined. By feeding horses upon this corn, typical fatal cases of staggers were produced in four out of seven cases.

This theory that toxic fungi cause forage-poisoning is not antagonistic to the facts in many of the more carefully observed outbreaks. The great variation in fungous growth

under different moisture conditions may explain the irregularity of the symptoms, as well as the occurrence of the disease under what may appear to be identical conditions. Many horses died as a result of eating mouldy baled hay, and as soon as this hay was eliminated the deaths ceased. Forage-poisoning, therefore, seems to be an auto-intoxication, due to certain chemical poisons or toxins formed by organismal activity.

Ruhl ('14), in a summary of the new theories concerning the etiology of pellagra, pointed out that investigators explain the casual relation of a corn diet to pellagra by four different physiological processes. However, these theories are inadequate, and serious objections are given to each. In this résumé we find that pellagra epidemics occur among people who have eaten corn that has been previously steamed, whereas persons in the same vicinity who have not eaten corn so treated were apparently not affected. It may be pointed out here that the steaming of corn before grinding will introduce conditions of moisture that favor the development of fungi, particularly *Rhizopus nigricans* and certain species of *Aspergillus*. In a moist condition the corn will become infected with fungi in a few days time; and after the corn has been dried, this fungous growth would no doubt pass unnoticed by the Italian peasants.

In the consideration of cryptococci, we do not find indications of toxic substances produced by these organisms. Galeotti and Pentimalli ('10) investigated the action of yeast toxin on the tissues of higher animals with three cultures of cryptococci obtained from tumors. The injection of the filtrate from liquid cultures or the injection of dead cultures gave negative results. However, the injection of living cells of certain cryptococci have proved fatal to rabbits, guinea-pigs, and dogs; and the organism seemed to show a selective action for the kidneys, the spleen, and the lungs. Loeb, Moore, and Fleisher ('13) were unable to find an extracellular toxin in cultures of the yeast-like fungus obtained from a carcinoma tissue. Death of the animals in this latter case was due to the rapid multiplication of yeast

cells in certain organs, more particularly the kidneys, which resulted in the blocking of the glomeruli and mechanical injury of the tissues. Cases of cryptomycoses in man have been reported in large numbers and appear to be less rare than they were formerly supposed.

Diseases of the skin are observed chiefly among persons living under conditions of uncleanliness, or among those who combine such conditions with a tendency to profuse perspiration. The disease does not penetrate into the skin itself, but consists, as Plaut has pointed out, of a simple saprophytism of the inciting agent upon the skin.

Certain species of *Oospora* and *Sporotrichum* which occur as skin parasites on man are non-pathogenic for other animals. Quincke obtained negative results with the spores of *Oospora (Achorion)* by subcutaneous, intraperitoneal, or intravenous injections into mice, rabbits, and dogs. Citron ('05) made intraperitoneal injections of 14-day growths of *Oospora* in beer-wort suspended in salt solution. Pseudotuberculosis of the peritoneum resulted from injections of either the living or the heat-sterilized fungus.

The question whether or not there are any species among the many known yeasts which are pathogenic for man and animals has been the subject of observation for some time and has been answered mostly in the negative. All the animal experiments made with true yeasts found in nature have given negative results. Raum ('91) and Neumayer ('91), working on the pathogenicity of yeasts up to the year 1891, came to the conclusion that cultivated yeasts are non-injurious to animals. Raum used ten fungi, including *Saccharomyces cerevisiae*, *S. Pastorianus*, *S. ellipsoideus*, and *S. turbidans*. In only one case of Neumayer's was an injurious effect on animals manifested. Fischer and Brebeck ('94) obtained negative results with ten species of *Mycoderma*, *Monilia candida* Hansen, and *Torula salmonicolor*. Rabinowitsch ('95), with fifty cultures of non-spore-forming yeasts, obtained evidence of an injurious action with seven of these fungi, but only in white rats, and in these cases it was necessary to use large quantities. San Felice has been able to

find but one species of *Torula* that is pathogenic for animals. Cao ('00) obtained positive results with nine of forty-one cultures of what he called *Oidium*. These results of Cao appear doubtful, for in many instances where the organisms were regained from the inoculated animals they were present in the brain. It is possible for fungi to live saprophytically in the intestines and after death spread to all parts of the body by a rapid growth in the blood vessels. These results of Cao, therefore, must be questioned as to their validity.

Cultures of the twelve yeast-like fungi considered in this paper did not produce death in animals or the formation of lesions. Only three of the fungi were isolated from inoculated animals; and in these cases the organism was found in the intestines, and in only one animal was the ioculated organism found in the lungs. The organism found in the lungs of a guinea-pig may have developed in the blood vessels after death. A repetition with inoculations of these same organisms gave negative results.

CONCLUSIONS

From a review of the literature on animal pathology we find that fungi—not including bacteria—are of secondary importance in the formation of lesions in animal bodies and usually appear secondarily in infected tissues.

On the other hand, certain fungi are to be considered of primary importance in those instances in which they prove toxic to animals if consumed in large quantities on infected foods.

One hundred and eighty cultures of yeast-like fungi were obtained from 850 different sources, but only twelve of these grow on a blood-serum medium at 37°C.

These twelve fungi include six cultures of *Torula*, five of *Alternaria*, and one of *Oospora*.

One culture of *Torula* and four of *Alternaria* produced small quantities of alcohol in sugar nutrient solutions.

In acid yeast-water solutions all twelve of these organisms bring about a change in the acidity reaction, there being a decrease in the acidity of all the acid nutrient solutions

except in the presence of acetic acid and in culture No. 4.

The results of thirty-four animal experiments were negative, in that the death of certain animals was not caused by the formation of lesions or abnormalities due to the organisms injected.

No extracellular toxins were obtained from the cultures of these twelve yeast-like organisms.

The results of these experiments and a review of literature on animal pathology indicate either that pathogenic yeast-like fungi do not occur in nature, or that if they are present, they are so few as to be met with only under exceptional conditions.

In conclusion, the writer wishes to express his thanks to Professor George T. Moore, for the suggestion of the problem and for numerous courtesies extended during the progress of the investigation while at the Missouri Botanical Garden; to Dr. E. L. Opie and Dr. W. S. Thomas, for suggestions and aid in the animal experiments which were carried out at the Washington University Medical School; to Professor W. C. Allee, for various suggestions and assistance in certain of the animal experiments; to Dr. Gayfree Ellison, for courtesies extended at the Bacteriological Laboratory of the University of Oklahoma; and to Mr. G. H. Smith of the University of Oklahoma, for assistance in reading the proofs.

Graduate Laboratory, Missouri Botanical Garden.

BIBLIOGRAPHY

Axamit, O. ('07). Überempfindlichkeitserscheinungen nach Hefeinjektion. Archiv f. Hyg. 62:15–54. *pl. 1.* 1907.

Ballin, ('08). Das Schicksal inhalierter Schimmelpilzporen, ein Beitrag zur Kenntnis des Infektionsweges durch Inhalation. Zeitschr. f. Hyg. 60:479–489. 1908.

Berthelat, C. J. ('03). Les Mucorinées pathogènes et les mucormycoses chez l'homme et chez les animaux. These. 127 pp. Paris, 1903.

Binaghi, R. ('96). Ueber das Vorkommen von Blastomyceten in den Epitheliomen und ihre parasitäre Bedeutung. Zeitschr. f. Hyg. 23:283–305. *pl. 4.* 1896.

Blakeslee, A. F., and Gartner, R. A. ('13). On the occurrence of a toxin in juice expressed from the bread mould, Rhizopus nigricans (Mucor stolonifer). Biol. Bul. 2:542–544. 1913.

Blumentritt, F. ('01). Ueber einen neuen, im Menschen gefundenen Aspergillus (Aspergillus bronchialis, n. sp.). Ber. d. deut. bot. Ges. 19:442–446. *pl. 22.* 1901.

————, ('05). Aspergillus bronchialis Blumentritt, und sein nächster Verwandter (Aspergillus fumigatus Fres.). *Ibid.* **23**:419–427. *pl. 19.* 1905.

Bodin, E., et Gautier, L. ('06). Note sur une toxine produite par l'Aspergillus fumigatus. [Centralbl. f. Bakt. I. **38**:700–701. 1906.]

Brouha, M. ('01). Sur les propriétés du sérum des cancereux au point de vue des anticorps des levures. *Ibid.* **30**:945–948. 1901.

Busse, O. ('03). Die Sprosspilze. In Kolle, W., und Wassermann, A., Handbuch der pathogenen Mikroorganismens **1**:661–700. *f. 1–8.* 1903.

Cao, G. ('00). Oidien und Oidiomykose. Zeitschr. f. Hyg. **34**:282–340. *pl. 3–4.* 1900.

Castellani, A. ('11). Observations on fungi of the genus Endomyces affecting man in the tropics. Centralbl. f. Bakt. I. **58**:236–238. *1 f.* 1911.

Cavara, V. ('14). Eine neue Form von Keratomykosis (Keratomykosis mucorina). *Ibid.* **72**:23–37. *pl. 1–2.* 1914.

Ceni, C. ('04). Localizzazione delle spore aspergillari nelle glandole mesenteriche dei pellagrosi e la loro consecutiva attenuazione. [*Ibid.* **35**:563. 1904.]

————, ('04a). Sulle proprietà patogene d. Penicillium glaucum nella etiologia della pellagra. [*Ibid.* 1904.]

————, ('07). Di una nuova specie di Aspergillus varians e delle sue proprietà patogene in rapporto coll'eziologia della pellagra. [*Ibid.* **39**:562–563. 1907.]

————, und Besta, C. ('03). Ueber die Toxine von Aspergillus fumigatus und Aspergillus flavescens und deren Beziehungen zur Pellagra. [*Ibid.* **33**:408. 1903.]

Chantemesse, A. ('91). Eine mykotische Pseudotuberkulose. [*Ibid.* **10**:442. 1891.]

Citron, J. ('05). Ueber das Verhalten der Favus- und Trichophytonpilze im Organismus. Zeitschr. f. Hyg. **49**:120–134. 1905.

Clerc, A., et Sartory, A. ('08). Étude biologique d'une levure isolée au cours d'une angine chronique. Compt. rend. Soc. Biol. **64**:135–137. 1908.

Colpe, J. ('94). Hefezellen als Krankheitserreger im weiblichen Genitalcanal. Archiv f. Gynäk. **47**:635–645. *2 f.* 1894.

Corselli, G., und Frisco, B. ('95). Pathogene Blastomyceten beim Menschen. Beiträge zur Aetiologie der bösartigen Geschwülste. Centralbl. f. Bakt. I. **18**:368–373. 1895.

Costantin, J. ('92). Note sur un cas de pneumomycose observé sur un chat par M. Neumann. Bul. Soc. Myc. **8**:57–59. 1892.

————, ('01). Sur les levûres des animaux. *Ibid.* **17**:145–148. 1901.

————, ('05). Recherches sur quelques Aspergillus pathogènes. Ann. d. Sci. Nat., Bot. IX. **2**:119–171. *pl. 5.* 1905.

————, et Lucet, A. ('03). Sur le Sterigmatocystis pseudonigra. Bul. Soc. Myc. **19**:33–44. 1903.

Curtis, F. ('95). Note sur un nouveau parasite humain, Megalococcus myxoides, trouvé dans un néoplasme de la région inguino-crurale. Compt. rend. Soc. Biol. **47**:715–718. 1895.

Fermi, C., und Aruch, E. ('95). Ueber eine neue pathogene Hefeart und über die Natur des sogenannten Cryptococcus farciminosus Rivoltae. Centralbl. f. Bakt. I. **17**:593–600. *4 f.* 1895.

Fischer, B., und Brebeck, C. ('94). Zur Morphologie, Biologie und Systematik der Kahmpilze, der Monilia candida Hansen und des Soorerregers. *pl. 1–2.* Jena, 1894.

except in the presence of acetic acid and in culture No. 4.

The results of thirty-four animal experiments were negative, in that the death of certain animals was not caused by the formation of lesions or abnormalities due to the organisms injected.

No extracellular toxins were obtained from the cultures of these twelve yeast-like organisms.

The results of these experiments and a review of literature on animal pathology indicate either that pathogenic yeast-like fungi do not occur in nature, or that if they are present, they are so few as to be met with only under exceptional conditions.

In conclusion, the writer wishes to express his thanks to Professor George T. Moore, for the suggestion of the problem and for numerous courtesies extended during the progress of the investigation while at the Missouri Botanical Garden; to Dr. E. L. Opie and Dr. W. S. Thomas, for suggestions and aid in the animal experiments which were carried out at the Washington University Medical School; to Professor W. C. Allee, for various suggestions and assistance in certain of the animal experiments; to Dr. Gayfree Ellison, for courtesies extended at the Bacteriological Laboratory of the University of Oklahoma; and to Mr. G. H. Smith of the University of Oklahoma, for assistance in reading the proofs.

Graduate Laboratory, Missouri Botanical Garden.

BIBLIOGRAPHY

Axamit, O. ('07). Überempfindlichkeitserscheinungen nach Hefeinjektion. Archiv f. Hyg. 62:15–54. *pl. 1.* 1907.

Ballin, ('08). Das Schicksal inhalierter Schimmelpilzporen, ein Beitrag zur Kenntnis des Infektionsweges durch Inhalation. Zeitschr. f. Hyg. 60:479–489. 1908.

Berthelat, C. J. ('03). Les Mucorinées pathogènes et les mucormycoses chez l'homme et chez les animaux. These. 127 pp. Paris, 1903.

Binaghi, R. ('96). Ueber das Vorkommen von Blastomyceten in den Epitheliomen und ihre parasitäre Bedeutung. Zeitschr. f. Hyg. 23:283–305. *pl. 4.* 1896.

Blakeslee, A. F., and Gartner, R. A. ('13). On the occurrence of a toxin in juice expressed from the bread mould, Rhizopus nigricans (Mucor stolonifer). Biol. Bul. 2:542–544. 1913.

Blumentritt, F. ('01). Ueber einen neuen, im Menschen gefundenen Aspergillus (Aspergillus bronchialis, n. sp.). Ber. d. deut. bot. Ges. 19:442–446. *pl. 22.* 1901.

————, ('05). Aspergillus bronchialis Blumentritt, und sein nächster Verwandter (Aspergillus fumigatus Fres.). *Ibid.* **23**:419–427. *pl. 19.* 1905.

Bodin, E., et Gautier, L. ('06). Note sur une toxine produite par l'Aspergillus fumigatus. [Centralbl. f. Bakt. I. **38**:700–701. 1906.]

Brouha, M. ('01). Sur les propriétés du sérum des cancereux au point de vue des anticorps des levures. *Ibid.* **30**:945–948. 1901.

Busse, O. ('03). Die Sprosspilze. In Kolle, W., und Wassermann, A., Handbuch der pathogenen Mikroorganismens **1**:661–700. *f. 1–8.* 1903.

Cao, G. ('00). Oidien und Oidiomykose. Zeitschr. f. Hyg. **34**:282–340. *pl. 3–4.* 1900.

Castellani, A. ('11). Observations on fungi of the genus Endomyces affecting man in the tropics. Centralbl. f. Bakt. I. **58**:236–238. *1 f.* 1911.

Cavara, V. ('14). Eine neue Form von Keratomykosis (Keratomykosis mucorina). *Ibid.* **72**:23–37. *pl. 1–2.* 1914.

Ceni, C. ('04). Localizzazione delle spore aspergillari nelle glandole mesenteriche dei pellagrosi e la loro consecutiva attenuazione. [*Ibid.* **35**:563. 1904.]

————, ('04[a]). Sulle proprietà patogene d. Penicillium glaucum nella etiologia della pellagra. [*Ibid.* 1904.]

————, ('07). Di una nuova specie di Aspergillus varians e delle sue proprietà patogene in rapporto coll'eziologia della pellagra. [*Ibid.* **39**:562–563. 1907.]

————, und Besta, C. ('03). Ueber die Toxine von Aspergillus fumigatus und Aspergillus flavescens und deren Beziehungen zur Pellagra. [*Ibid.* **33**:408. 1903.]

Chantemesse, A. ('91). Eine mykotische Pseudotuberkulose. [*Ibid.* **10**:442. 1891.]

Citron, J. ('05). Ueber das Verhalten der Favus- und Trichophytonpilze im Organismus. Zeitschr. f. Hyg. **49**:120–134. 1905.

Clerc, A., et Sartory, A. ('08). Étude biologique d'une levure isolée au cours d'une angine chronique. Compt. rend. Soc. Biol. **64**:135–137. 1908.

Colpe, J. ('94). Hefezellen als Krankheitserreger im weiblichen Genitalcanal. Archiv f. Gynäk. **47**:635–645. *2 f.* 1894.

Corselli, G., und Frisco, B. ('95). Pathogene Blastomyceten beim Menschen. Beiträge zur Aetiologie der bösartigen Geschwülste. Centralbl. f. Bakt. I. **18**:368–373. 1895.

Costantin, J. ('92). Note sur un cas de pneumomycose observé sur un chat par M. Neumann. Bul. Soc. Myc. **8**:57–59. 1892.

————, ('01). Sur les levûres des animaux. *Ibid.* **17**:145–148. 1901.

————, ('05). Recherches sur quelques Aspergillus pathogènes. Ann. d. Sci. Nat., Bot. IX. **2**:119–171. *pl. 5.* 1905.

————, et Lucet, A. ('03). Sur le Sterigmatocystis pseudonigra. Bul. Soc. Myc. **19**:33–44. 1903.

Curtis, F. ('95). Note sur un nouveau parasite humain, Megalococcus myxoides, trouvé dans un néoplasme de la région inguino-crurale. Compt. rend. Soc. Biol. **47**:715–718. 1895.

Fermi, C., und Aruch, E. ('95). Ueber eine neue pathogene Hefeart und über die Natur des sogenannten Cryptococcus farciminosus Rivoltae. Centralbl. f. Bakt. I. **17**:593–600. *4 f.* 1895.

Fischer, B., und Brebeck, C. ('94). Zur Morphologie, Biologie und Systematik der Kahmpilze, der Monilia candida Hansen und des Sooerregers. *pl. 1–2.* Jena, 1894.

Fürbringer, P. ('76). Beobachtungen über Lungenmycose beim Menschen. Virchow's Archiv **66**:330–365. *pl. 15.* 1876.

Galeotti, G., und Pentimalli, F. ('10). Ueber die von pathogenen Hefen und ihren Toxinen erzeugten Neubildungen. Centralbl. f. Bakt. I. **56**:312–325. *pl. 1–2.* 1910.

Gedoelst, L. ('02). Les champignons parasites de l'homme et des animaux domestiques. 199 pp. Bruxelles, 1902.

Grawitz, P. ('77). Beiträge zur systematischen Botanik der pflanzlichen Parasiten mit experimentellen Untersuchungen über die durch sie bedingten Krankheiten. Virchow's Archiv **70**:546–598. *pl. 18–19.* 1877.

Grohe, M. ('70). Verhandlungen ärztlicher Gessellschaften. [Berl. klin. Wochenschr. **7**:8–9. 1870.]

Gruby, ('43). Recherches sur la nature, le siége et le développement du Porrigo decalvans ou Phytoalopécie. Compt. rend. Acad. Paris. **17**:301–303. 1843.

————, ('44). Recherches sur les cryptogames qui constituent la maladie contagieuse du cuir chevelu décrite sous la nom de Teigne tondante (Mahon) Herpes tonsurans (Cazenave). *Ibid.* **18**:583–585. 1844.

Guéguen, F. ('05). Quelques mots sur les Aspergillus pathogènes. Bul. Soc. Myc. **21**:243–245. 1905.

————, ('08). Les champignons parasites de l'espèce humaine. Rev. Sci. V. **9**:745–752. 1908.

————, ('09). Aspergillus fontoynonti nova sp., parasite probable des nodosités juxta-articulaires. Compt. rend. Soc. Biol. **66**:1052–1053. 1909.

Hatch, W. K., and Row, R. ('00). Fungus disease of the ear. The Lancet **2**:1561–1564. *1 f.* 1900.

Hektoen, L. ('00). Ein neuer pathogener Pilz — Sporothrix von Schenk. Centralbl. f. Bakt. I. **27**:682–683. 1900.

Hiekel, R. ('06). Beiträge zur Morphologie und Physiologie des Soorerregers (Dematium albicans Laurent=Oidium albicans Robin). K. Akad. Wiss., Wien, math- naturw. Kl., Sitzungsber. **115**:159–197. *pl. 1–2.* 1906.

Jakowski, M. ('89). Otomycosis mucorina. Centralbl. f. Bakt. I. **5**:388–389. 1889.

Jensen, V. ('03). Ueber die Entwickelung der durch subcutane Einimpfung von Saccharomyces neoformans (San Felice) hervorgerufenen Knötchen. Zeitschr. f. Hyg. **45**:298–308. *pl. 4.* 1903.

Köllner, ('07). Schimmelpilzerkrankung der Sklera. [Centralbl. f. Bakt. I. **40**:432. 1907.]

Klug, A. ('04). Der Hausschwamm, ein pathogener Parasit des menschlichen und tierischen Organismus, speziell seine Eigenschaft als Erreger von Krebsgeschwülsten. [*Ibid.* II. **11**:234–235. 1904.]

Leber, T. ('79). Keratomycosis aspergillina als Ursache von Hypopyonkeratitis. Archiv f. Opthalm. **25**²:285–301. 1879.

—— – , ('82). Ueber die Wachsthumsbedingungen der Schimmelpilze im menschlichen und thierischen Körper. Berl. klin. Wochenschr. **19**:161–164. 1882.

Leopold, G. ('00). Untersuchungen zur Aetiologie des Carcinoms und über die pathogenen Blastomyceten. Archiv f. Gynäk. **61**:77–120. *pl. 1–6.* 1900.

Lichtheim, L. ('82). Ueber pathogene Schimmelpilze. Berl. klin. Wochenschr. **19**:129–132, 147–152. 1882.

Lindt, W. ('86). Mittheilungen über einige neue pathogene Schimmelpilze. Archiv f. exp. Path. u. Pharm. **21**:269–298. *pl. 2–3.* 1886.

————,('89). Ueber einen neuen pathogenen Schimmelpilz aus dem menschlichen Gehörgang. *Ibid.* **25**:257–271. *f. 1–11.* 1889.

Linossier, G., et Roux, G. ('99). Sur la morphologie et la biologie du champignon du muguet. Compt. rend. Acad. Paris **109**:752–755. 1899.

Loeb, L., Moore, G. T., und Fleisher, M. S. ('13). Ueber das Vorkommen von Hefen in menschlichen Tumoren mit Versuchen über das Wachstum einer pathogenen Hefe im Tierkörper. Centralbl. f. Bakt. I. **67**:450–472. 1913.

Lucet, A. ('01). Contribution à l'étude etiologique et pathogénique de la langue noire pileuse. Archiv. de Par. **4**:262–287. 1901.

————,et Costantin, J. ('00). Rhizomucor parasiticus, espèce pathogène de l'homme. Rev. Gén. Bot. **12**:81–98. *pl. 3.* 1900.

————, ————, ('01). Contributions à l'étude des Mucorinées pathogènes. Archiv. d. Par. **4**:362–408. *f. 1–31.* 1901.

Maffucci, A., und Sirleo, L. ('98). Ueber die Blastomyceten als Infectionserreger bei bösartigen Tumoren. Zeitschr. f. Hyg. **27**:1–30. *pl. 1.* 1898.

Matruchot, L. ('10). Sur un nouveau groupe de champignons pathogènes, agents des Sporotrichoses. Compt. rend. Acad. Paris **150**:543–545. 1910.

- ————, et Dassonville, C. ('98). Sur le champignon de l'herpes (Trichophyton) et les formes voisines, et sur la classification des Ascomycètes. Bul. Soc. Myc. **15**:240–253. *f. 1.* 1898.

————, ————, ('99). Sur la position systématique des Trichophyton et des formes voisines dans la classification des champignons. Compt. rend. Acad. Paris **128**:1411–1413. 1899.

————, ————, ('99). Sur le Ctenomyces serratus Eidam, comparé aux champignons des Teignes. Bul. Soc. Myc. **15**:305–310. 1899.

————, ————, ('00). Sur une forme de reproduction d'ordre élevé chez les Trichophyton. *Ibid.* **16**:201–208. 1900.

————, et Ramond ('05). Un type nouveau de champignon pathogène chez l'homme. Compt. rend. Soc. Biol. **59**:378–380. 1905.

Michailow, S. ('11). Zwei neue Fälle von Pilzbefunden im Bereiche des Zentralnervensystems. Centralbl. f. Bakt. I. **60**:500–511. *f. 1–5.* 1911.

Mohler, J. R. ('14). Cerebrospinal meningitis (''forage poisoning''). U. S. Dept. Agr., Bul. **65**:1–14. 1914.

Neumayer, J. ('91). Untersuchungen über die Wirkungen der verschiedenen Hefearten, welche bei der Bereitung weingeistiger Getränke vorkommen, auf den thierischen und menschlichen Organismus. Archiv f. Hyg. **12**:1–60. 1891.

Otto, M. ('07). Ueber die Giftwirkung einiger Stämme von Aspergillus fumigatus und Penicillium glaucum, nebst einigen Bemerkungen über Pellagra. [Centralbl. f. Bakt. I. **39**:563–565. 1907.]

Paltauf, A. ('85). Mycosis mucorina. Virchow's Archiv **102**:543–564. *pl. 6.* 1885.

Peck, C. H. ('91). Species of plants not before reported. N. Y. State Mus., Ann. Rept. **44**:127–187. 1891.

Pianeze, G. ('96). Beitrag zur Histologie und Aetiologie des Carcinoms. Beitr. z. path. Anat. (Zeigler). 1–193. 1896.

Pinoy, E. ('11). Forme du Sporotrichum Beurmanni dans les lésions humaines. Compt. rend. Acad. Paris **152**:286–288. 1911.

Plaut, H. C. ('03). Die Hyphenpilze oder Eumyceten. In Kolle, W., und Wassermann, A., Handbuch der pathogenen Mikroorganismen 1:526–660. *f. 1–55.* 1903.

Pound, R. ('01). An addition to the parasites of the human ear. Am. Micr. Soc., Trans. 22:81–88. *pl. 18.* 1901.

Rabinowitsch, L. ('95). Untersuchungen über pathogene Hefearten. Zeitschr. f. Hyg. 21:11–24. 1895.

Rajat, H., et Péju, G. ('07). Le parasite du muguet et sa place dans la classification botanique. Compt. rend. Soc. Biol. 61:617–618. 1907.

Raum, J. ('91). Zur Morphologie und Biologie der Sprosspilze. Zeitschr. f. Hyg. 10:1–50. *pl. 1–2.* 1891.

Ribbert, M. ('85). Beiträge zur Localisation der Infections-krankheiten. Duet. med. Wochenschr. 11:717–719. 1885.

Roger H., Bory, L., et Sartory, A. ('09). Note sur une nouvelle Oospora pathogène (Oospora pulmonalis). Compt. rend. Soc. Biol. 66:150–152. 1909.

———, ———, ———, ('09[a]). Oospora buccalis. *Ibid.* 301–303. 1909.

Roncali, D. B. ('95). Die Blastomyceten in den Adenocarcinomen des Ovariums. Centralbl. f. Bakt. I. 18:353–368. *pl. 2.* 1895.

———, ('95[a]). Die Blastomyceten in den Sarkomen. *Ibid.* 432–434. 1895.

Ruhl, K. ('14). Die neueren Lehren über die Ätiologie der Pellagra. *Ibid.* 62:321–340. 1914.

San Felice, F. ('95–'03). Ueber die pathogene Wirkung der Blastomyceten. I. Zeitschr. f. Hyg. 21:32–58. *pl. 1–2.* 394–420. *pl. 9–10.* 1895–96; *Ibid.* II. 22:171–200. *pl. 2–3.* 1896; *Ibid.* V. 29:463–504. *pl. 4–8.* 1898; *Ibid.* VI. 44:364–396. *pl. 6–7.* 1903.

Sartory, A. ('07). Étude biologique de Cryptococcus (Saccharomyces) glutinis Fres. (Kütz.). Bul. Soc. Myc. 23:87–89. 1907.

———, ('11). Contribution a l'étude de quelques Oospora pathogènes. *Ibid.* 27:160–171. *f. 1–11.* 1911.

Schubert, P. ('85). Zur Casuistik der Aspergillusmykosen. Deut. Archiv f. klin. Med. 36:162–183. *pl. 3.* 1885.

Schwartz, G. ('06). Ein operativ behandelter Fall von Pneumonomykosis aspergillina. [Centralbl. f. Bakt. I. 38:295. 1906.]

Siebenmann, F. ('89). Die Schimmelmykosen des menschlichen Ohres. Wiesbaden, 1899. [Cited by Plaut, '03.]

Sticker, G. ('00). Schimmelpilzkrankheiten der Lunge. Spec. path. u. ther. Nothnagel. 14:156–192. 1900.

Sturli, A. ('10). Über ein in Schimmelpilzen (Penicillium glaucum) vorkommendes Gift. [Centralbl. f. Bakt. II. 25:334. 1910.]

Tokishige, H. ('96). Ueber pathogene Blastomyceten. *Ibid.* I. 19:105–113. *pl. 3–5.* 1896.

Troisier, E., et Achalme, P. ('93). Sur une angine parasitaire causée par une levure et cliniquement semblable au muguet. Archiv. Méd. Exp. et d'Anat. Path. 5:29–37. *f. 1–3.* 1893.

Uhthoff, W. ('83). Beiträge zur pathologischen Anatomie des Auges. Archiv f. Opthalm. 29[3]:167–190. *pl. 3–5.* 1883.

Virchow, R. ('56). Beiträge zur Lehre von den beim Menschen vorkommenden pflanzlichen Parasiten. Virchow's Archiv 9:557–593. 1856.

Vuillemin, P. ('98). Les caractères spécifiques du champignon du muguet (Endomyces albicans). Compt. rend. Acad. Paris 127:630–633. 1898.

———, ('12). Sur un champignon parasite de l'homme, Glenospora Graphii (Siebenmann). *Ibid.* **154**:141–143. 1912.

———, et Legrain, E. ('00). Sur un cas de Saccharomyces humaine. Archiv. d. Par. **3**:237–268. *f. 1–3.* 1900.

Wehmer, C. ('98). Die Pilzgattung Aspergillus. Soc. Phys. et d'Hist. Nat., Genève, Mém. **33**:1–157. 1898.

———, ('04). Der Aspergillus des Tokelau. Centralbl. f. Bakt. I. **35**:140–146. *f. 1–9.* 1904.

Weichselbaum, A. ('78). Beobachtung von Pneumomycosis aspergillina. Wien med. Wochenschr. **28**:1290–1291. 1878.

Will, H. ('10). Beiträge zur Kenntnis der Gattung Mycoderma. Centralbl. f. Bakt. II. **28**:1–37. *15 f.* 1910.

Annals
of the
Missouri Botanical Garden

Vol. 3 SEPTEMBER, 1916 No. 3

THE MISSOURI AGRIMONIES

BENJAMIN FRANKLIN BUSH

Having collected some interesting specimens of *Agrimonia* in 1915, that I could not place satisfactorily by the manuals, I was led to make a closer examination of the species of this genus, and through the kindness of Dr. Moore, of the Missouri Botanical Garden, I was enabled to study all the Missouri specimens of this genus in the Garden herbarium.

For more than sixty years the species of *Agrimonia* have been but little understood, that is, up to the year 1893, when Britton's 'Manual'[1] began to be of influence in the way of specific names. The genus seems to have been very much neglected in Missouri, for I have seen only sixteen specimens collected in the state prior to 1893. This seems rather remarkable in a genus of so many species which are so conspicuous in the field, but the fact is due in large part to the prevailing impression that we had only two American species, one of which was also found in Europe, and therefore it was of no importance to make specimens of such widely distributed species. Such an impression also prevailed in many other genera at that time, notable examples of which are *Ranunculus repens, Scrophularia nodosa, Amaranthus Blitum,* and *Portulaca oleracea.*

Of the sixteen specimens examined, collected before 1893, six were labeled *A. parviflora,* five correctly, but one is *A.*

[1]Britton, N. L. Manual northeastern states and Canada. 1891.

rostellata. Only two specimens of *A. rostellata* are included in this lot, one labeled *A. parviflora,* as cited above, and the other being called *A. striata.* Only one specimen of *A. platycarpa* was found and that was labeled *A. Eupatoria.* The remaining eight specimens are all *A. pubescens,* of which three are indicated as *A. Eupatoria,* one *A. striata,* and four are left blank as to specific name.

It will thus be seen that these sixteen earlier collections bear but three names, six being called *A. parviflora,* four *A. Eupatoria,* and two being given the name of *A. striata,* while four collectors did not signify any choice of specific names. It is true that one of these sheets bears a label on which the species is indicated as *A. microcarpa,* but this specimen came to me unnamed, and sometime in 1893 I affixed this name to the specimen, being led to do this by Britton's 'Manual.'

It is hard to conceive how two such unlike species as *A. rostellata* and *A. pubescens* should both be named *A. striata* by the collectors, but in those days *A. striata* was little understood, and Michaux's species was not found in any of the manuals or floras, although it was well characterized and is one of our most distinct species.

Several authors have studied and described species and varieties of *Agrimonia,* notably Solander,[1] Michaux,[2] Muhlenberg,[3] Pursh,[4] Torrey and Gray,[5] Wallroth,[6] Britton,[7] Bicknell,[8] and Kearney.[9]

Our oldest species is *A. parviflora* Solander, a distinct species by itself, and one generally understood. The next species to be described is Michaux's *A. striata,* here mentioned because it was formerly confused with *A. rostellata*

[1]Ait. Hort. Kew. 2:129–131. 1789.
[2]Fl. Bor. Am. 1:287. 1803.
[3]Cat. Pl. Am. Sept. 47. 1813.
[4]Fl. Am. Sept. 1:335–336. 1816.
[5]Fl. N. Am. 1:431. 1840.
[6]Beitr. Bot. 1':1–61. 1842.
[7]Bull. Torr. Bot. Club 19:221. 1892.
[8]*Ibid.* 23:508–523. 1896.
[9]*Ibid.* 24:565. 1897.

and *A. pubescens,* and which may ultimately be found in northeastern Missouri.

Muhlenberg, in 1813, indicated *A. pumila* as a good species but unfortunately did not describe it, and also described *A. Eupatoria,* var. *hirsuta,* which eighty-three years later was raised to specific rank. Torrey and Gray, in 1840, described *A. Eupatoria,* var. *mollis,* which fifty-two years afterward was described as a species. Wallroth, in 1842, monographed the genus, giving six of our species, one, *A. microcarpa,* having been described as *A. pumila* by Muhlenberg. Most of Wallroth's names are valid and are the ones that will be accepted in American botany.

Britton, in 1892, half a century since any work was done on the genus, described *A. mollis,* based on the *A. Eupatoria,* var. *mollis* of Torrey and Gray. Bicknell, in 1896, raised Muhlenberg's *A. Eupatoria,* var. *hirsuta* to specific rank, giving at the same time a description of this and a new species, *A. Brittoniana.* He was apparently unaware that Wallroth had already described the former species as *A. grypposepala,* and that the latter was described by Michaux in 1803 as *A. striata.* Kearney, in 1897, described a variety, *A. mollis,* var. *Bicknellii,* which afterwards was found to be the same as *A. mollis,* described by Wallroth in 1842 as *A. pubescens.*

Prior to 1893, when Britton's 'Manual' began to influence the names in this genus, but three specific names were in use for species of *Agrimonia* in the eastern states, *A. Eupatoria, A. parviflora,* and *A. striata,* the latter not being mentioned in any manual or flora of recent date, and the name applied also to both *A. rostellata* and *A. pubescens.*

Muhlenberg, in his 'Catalogue,' recognized and indicated several species and varieties in this genus, but these were not accepted until after 1891, and his names are *nomina nuda.* Torrey and Gray, in 1840, described several species, among which was *A. Eupatoria,* var. *mollis,* afterwards raised to specific rank by Britton in 1892. Wallroth's monograph of this genus, in 1842, was not recognized by any of

the manuals or floras until 1891, when Britton in his 'Manual' accepted some of the species.

Wood, in the last edition of his 'Botanist and Florist,' in 1876, gives only *A. Eupatoria* and *A. parviflora*, while Tracy, in his 'Flora of Missouri,' in 1885, catalogues the same species, the latter correct, the former including *A. pubescens* and *A. rostellata*.

Gray, in the sixth edition of his 'Manual,' in 1890, gives but two species, *A. Eupatoria* and *A. parviflora*, the latter correct, the former including all the other species. Eggert, in his catalogue,[1] gives these same two species, *A. parviflora* being correct, but *A. Eupatoria* is applied to *A. rostellata*. Chapman, in his 'Flora,'[2] describes *A. Eupatoria*, *A. Eupatoria*, var. *mollis*, and *A. parviflora*, the last two correct, the other being *A. gryposepala*.

Having thus reviewed the history of the species found, or likely to be found, I now present for the Missouri species the following key:

1. Fruiting hypanthium with several series of bristles, the lower reflexed; racemes and leaves beneath with loose spreading hairs..... .....*1. Agrimonia gryposepala*

1. Fruiting hypanthium with 2–4 series of bristles, the latter erect, ascending, or merely spreading; racemes and leaves beneath closely or softly pubescent, or glabrous.

   2. Racemes and leaves glabrous or nearly so, glandular-granuliferous; root tuberous-thickened.....*2. Agrimonia rostellata*

   2. Racemes and lower surface of the leaves decidedly hairy.

      3. Roots not tuberous; leaflets not conspicuously glandular-granuliferous beneath. .....*6. Agrimonia parviflora*

      3. Roots tuberous-thickened; leaflets not glandular-granuliferous or only slightly so, velvety-pubescent beneath.

         4. Fruiting hypanthium campanulate or turbinate, longer than broad; rim of fruit not conspicuous; leaflets of the lower leaves 7–13; long hairs of the stem erect or ascending ....*5. Agrimonia pubescens*

         4. Fruiting hypanthium broadly obconic, nearly as broad as long or broader, shorter than the sepals, with a prominent rim; lower leaves with 3–5, rarely 7, leaflets; long hairs of the stem divaricate.

[1]Catalogue of the phaenogamus and vascular cryptogamous plants in the vicinity of St. Louis, Mo. 1891.

[2]Flora southern United States. 1897.

5. Leaves usually crowded on the lower part of the stem; leaflets 3 or 5, with the lower pair much reduced, rounded at the apex; fruiting hypanthium as broad as long .... *3. Agrimonia microcarpa*

5. Leaves scattered on the stem; leaflets 5–7, acute at the apex; fruiting hypanthium as broad as long, or usually broader ..... *4. Agrimonia platycarpa*

1. Agrimonia gryposepala Wallr. Beitr. Bot. 1[1]:49. 1842.

Agrimonia Eupatoria Pursh, Fl. Am. Sept. 1:335. 1816, not L. 1753.

Agrimonia Eupatoria Gray, Manual, ed. 6, 161. 1890, not ed. 2. 1753.

Agrimonia Eupatoria Chapman, Fl. Southern U. S. 133. 1897, not L. 1753.

Agrimonia Eupatoria, var. *hirsuta* Muhl. Cat. 47 (hyponym). 1813; Barton, Fl. Phila. Prodr. 53. 1815.

Agrimonia hirsuta (Muhl.) Bickn. Bull. Torr. Bot. Club 23:509. 1896, not *Agrimonia hirsuta* Boug. 1842.

The only specimens seen are the following:

Ethel, *Bush 7842,* Sept. 23, 1915, good complete plants.

2. Agrimonia rostellata Wallr. Beitr. Bot. 1[1]:42. 1842.

Agrimonia Eupatoria Gray, Manual, ed. 6, 161. 1890, not L. 1753.

Agrimonia Eupatoria, var. *glabra* Muhl. Cat. 47 (hyponym). 1813.

Agrimonia Eupatoria, var. *parviflora* Hook. Fl. Bor. Am. 1:197. 1840.

Agrimonia parviflora Seringe, in DC. Prodr. 2:588. 1825, not *Agrimonia parviflora* Soland. in Ait. Hort. Kew. 2:130. 1789.

Agrimonia americana Lucae, in Wallr. Beitr. Bot. 1[1]:43, as synonym. 1842.

Agrimonia striata Bickn. Bull. Torr. Bot. Club 23:512. 1896, not *Agrimonia striata* Michx. 1803.

The following specimens have been examined:

Williamsville, Wayne Co., *Trelease 149,* Sept. 9, 1897, a small, weak, poor specimen, but undoubtedly this species, in flower and young fruit, Herb. No. 52,255; Swan, Taney Co.,

Bush 560, Sept. 24, 1899, a small, weak plant in young flower, Herb. No. 52,256; Monteer, Shannon Co., *Bush 746,* Aug. 22, 1901, a complete specimen in flower and fruit, Herb. No. 52,257; East Bertig, Dunklin Co., *Trelease,* Oct. 28, 1897, a small, weak plant with fruit all fallen off, Herb. No. 52,254; Meramec Highlands, St. Louis Co., *A. G. Johnson,* July 29, 1905, the upper part of a robust plant in flower and young fruit, Herb. No. 52,252; Spring River, Jasper Co., *Trelease 982,* Sept. 18, 1898, a fine, complete plant with nearly all the fruit fallen off, Herb. No. 52,253; Thornton, Clay Co., *Mackenzie 642,* Oct. 18, 1901, a complete plant with all the fruit fallen off, Herb. No. 52,258; Campbell, Dunklin Co., *Bush 110,* Aug. 16, 1895, a small, weak plant not yet in flower, Herb. No. 52,259; Dodson, Jackson Co., *Bush 107,* Aug. 26, 1895, a complete plant in full-grown fruit, Herb. No. 52,260; Flat River, St. Francois Co., *Trelease,* Oct. 13, 1897, a poor, weak plant with the fruit all fallen off, Herb. No. 52,261; Webb City, Jasper Co., *Bush 6026,* July 23, 1910, a good, complete specimen in flower and young fruit, Herb. No. 52,262; Fern Glen, St. Louis Co., *A. G. Johnson,* July 14, 1906, the upper part of a plant not yet in flower, with narrower leaves than usual, but evidently belonging to this species, Herb. No. 52,263; Meramec Highlands, St. Louis Co., *Eggert,* July 10, 1897, a fine, large plant scarcely yet in flower, Herb. No. 52,264; Monteer, Shannon Co., *Bush 4896,* Oct. 10, 1907, a poorly pressed, large plant in fine fruit, Herb. No. 52,265; Sulphur Springs, Jefferson Co., *Trelease,* Oct. 23, 1899, the plant marked A, the fruit all fallen off, Herb. No. 52,266; Winona Lodge, James River, Greene Co., *Trelease,* July 22, 1897, a fine, full plant just coming into flower, Herb. No. 52,267; Jefferson City, Cole Co., *Dr. O. Krause,* June, 1866, a fairly complete plant just coming into flower, labeled *A. parviflora,* Herb. No. 52,268; Williamsville, Wayne Co., *Trelease,* Sept. 9, 1897, a large, complete plant with some fruit still on the branches, Herb. No. 52,269; Allenton, St. Louis Co., *Letterman,* July 10, 1888, a fine complete plant in flower and fruit, labeled *A.*

striata, Herb. No. 52,270; Swope Park, Jackson Co., *Mackenzie,* July 4, 1896, the plant marked B, a fine complete plant just coming into flower, Herb. No. 52,292; Pilot Knob, Iron Co., *Glatfelter,* Aug. 20, 1895, the plant marked A, a small plant with all the fruit fallen off, labeled *A. microcarpa,* Herb. No. 52,292.

3. **Agrimonia microcarpa** Wallr. Beitr. Bot. **1**[1]:39. 1842.

Agrimonia pumila Muhl. Cat. 47 (hyponym). 1813; Bicknell, Bull. Torr. Bot. Club **23**:514. 1896.

Only the following have been examined:

Terre Bleue Creek, St. Francois Co., *Trelease,* Aug. 29, 1898, a small plant, 3 dm. tall, with five or six leaves near the base, in young fruit and flower, Herb. No. 52,271.

4. **Agrimonia platycarpa** Wallr. Beitr. Bot. **1**[1]:38. 1842.

Agrimonia Eupatoria Gray, Manual, eds. 1–6, in part, and of many other American authors, not L. 1753.

The following specimens have been examined:

Dodson, Jackson Co., *Bush 851,* Sept. 2, 1900, a very good, whole plant in ripe fruit, Herb. No. 52,273; Atchison Co., *Bush,* Aug. 23, 1893, a complete specimen in full fruit, which I refer to this species, Herb. No. 52,319; Cliff Cave, St. Louis Co., *J. B. S. Norton,* Aug. 26, 1899, a very poor specimen with no fruit, but which may well belong to this species, Herb. No. 52,394; Courtney, Jackson Co., *Bush 253,* Aug. 21, 1896, a complete specimen in good fruit, which appears to belong to this species, Herb. No. 52,320; Springfield, Greene Co., *Dewart 115,* July 31, 1882, one small and one tall slender plant in poor condition, the plant marked B apparently belonging to this species, labeled *A. Eupatoria,* Herb. No. 52,316; Hannibal, Marion Co., *Davis 6210,* Aug. 24, 1915, a full, complete plant in fruit; Swope Park, Jackson Co., *Bush,* Oct. 14, 1915, full, complete plants in fine fruit.

5. **Agrimonia pubescens** Wallr. Beitr. Bot. **1**[1]:45. 1842.

Agrimonia Eupatoria, var. *mollis* Torr. & Gray, Fl. N. Am. **1**:431. 1840.

Agrimonia Eupatoria Gray, Manual, eds. 1–6, in part, and of many other American authors, not L. 1753.

Agrimonia parviflora Kinn, in Wallr. Beitr. Bot. 1[1]:45, as synonym. 1842, not *A. parviflora* Soland. 1789.

Agrimonia mollis (T. & G.) Britton, Bull. Torr. Bot. Club 19:221. 1892.

The following specimens were examined:

Seligman, Barry Co., *Dewart*, Aug. 21, 1892, a complete plant in flower and fruit, with no specific name, Herb. No. 52,272; Washington Co., *Wislizenus 107*, July 23, 1885, several pieces apparently all belonging to one plant, labeled *A. Eupatoria*, Herb. No. 52,291; Jefferson Barracks, St. Louis Co., *Norton*, Nov. 17, 1900, a very poor specimen without leaves or fruit, but evidently this species, Herb. No. 52,290; Roaring River, Barry Co., *Trelease 983*, Sept. 7, 1898, a tall plant cut into two pieces, with the fruit all fallen off, Herb. No. 52,296; Flat River, St. Francois Co., *Trelease*, Oct. 13, 1897, two plants, one very poor, the other with ripe fruit, Herb. No. 52,297; St. Louis, St. Louis Co., *Engelmann*, Aug., 1842, labeled *A. striata*, Herb. No. 52,298; Seligman, Barry Co., *Dewart*, Aug. 21, 1892, a tall plant in fruit, not named, Herb. No. 52,299; Chain of Rocks, St. Louis Co., *Craig*, Oct. 4, 1908, a poorly pressed, tall plant with nearly all the fruit fallen off, Herb. No. 52,300; Webb City, Jasper Co., *Bush 6038*, July 23, 1910, a fine, large, complete plant just coming into flower, Herb. No. 52,301; Monteer, Shannon Co., *Bush 6136*, Aug. 8, 1910, a tall, fine plant just coming into flower, Herb. No. 52,302; Monteer, Shannon Co., *Bush 6135*, Aug. 8, 1910, a slender, complete plant in flower and young fruit, Herb. No. 52,303; St. Louis, St. Louis Co., *Glatfelter*, 1889, the top of a tall, robust plant just coming into flower, labeled *A. Eupatoria*, Herb. No. 52,304; west of St. Louis, St. Louis Co., *Hitchcock*, July 26, 1890, a tall, robust plant with all of the fruit fallen off, not named, Herb. No. 52,305; Cass Co., *Broadhead*, Aug. 11, 1884, two very poor specimens of tops of plants, without flowers or fruit, but evidently this species, Herb. No. 52,306;

Newton Co., *Bush,* July 15, 1893, a small plant in fruit, labeled *A. Eupatoria,* Herb. No. 52,307; Greene Co., *Blankinship,* Aug. 13, 1889, a slender plant broken in two pieces, in mature fruit, labeled *A. microcarpa* by me, Herb. No. 52,308; Creve Coeur Lake, St. Louis Co., *Norton,* Sept. 17, 1898, a poor specimen as to leaves, but with good fruit, Herb. No. 52,309; Kansas City, Jackson Co., *Bush 1747,* July 29, 1902, a full, complete specimen in flower and fruit, Herb. No. 52,310; Webb City, Jasper Co., *Palmer 306,* Aug. 30, 1902, a specimen in poor condition, with fruit all fallen off, Herb. No. 52,311; Independence, Jackson Co., *Bush 272,* Sept. 12, 1895, a poor specimen as to leaves, but with good fruit, Herb. No. 52,312; Monteer, Shannon Co., *Bush 745,* Aug. 22, 1901, a fine, large plant in good fruit, Herb. No. 52,313; Swan, Taney Co., *Bush 721,* Oct. 1, 1899, a poor plant as to leaves, but with fine large fruit, Herb. No. 52,314; North Kansas City, Clay Co., *Mackenzie,* Sept. 12, 1897, a large, fine specimen in fine fruit, Herb. No. 52,315; Springfield, Greene Co., *Dewart 115,* July 31, 1892, the plant marked A apparently belonging to this species, Herb. No. 52,316; Bismarck, St. Francois Co., *Bush 37,* Sept. 12, 1893, the top of a fine plant in fine fruit, Herb. No. 52,317; McDonald Co., *Bush,* Sept. 1, 1893, the top of a tall plant in good condition, but just coming into flower, Herb. No. 53,318; Sulphur Springs, Jefferson Co., *Trelease,* an upper and lower part of a poor plant without fruit, Herb. No. 52,266.

6. **Agrimonia parviflora** Soland. in Ait. Hort. Kew. **2**:130. 1789.

Agrimonia Eupatoria Michx. Fl. Bor. Am. **1**:287. 1803, not *A. Eupatoria* L. 1753.

Agrimonia suaveolens Pursh. Fl. Am. Sept. **1**:336. 1816.

Agrimonia serrifolia Wallr. Beitr. Bot. **1**[1]:40. 1842.

Agrimonia Eupatoria, var. *americana* Kinn, in Wallr. Beitr. Bot. **1**[1]:40. 1842, as synonym.

Agrimonia polyphylla Urban, Symb. Ant. **7**:227. 1912.

Specimens examined:

Marble Cave, Stone Co., *Trelease*, Sept. 11, 1898, a large, fine plant in fine fruit, Herb. No. 52,274; Little Blue, Jackson Co., *Bush 258*, Aug. 9, 1896, a good specimen just coming into flower, Herb. No. 52,275; Texas Co., *Blankinship*, Aug. 6, 1888, a good specimen just in young fruit, Herb. No. 52,276; St. Louis Co., *Eggert*, July 27, 1878, a good, full specimen scarcely in flower, Herb. No. 52,277; Pilot Knob, Iron Co., *Russell*, Sept., 1897, a good middle portion of a plant without flowers or fruit, Herb. No. 52,278; McDonald Co., *Bush*, Sept. 1, 1893, a good, full specimen in flower and fruit, Herb. No. 52,279; Jasper Co., *Bush*, Aug. 16, 1893, a good terminal portion of a large plant in flower and young fruit, Herb. No. 52,280; Purcell, Jasper Co., *Palmer 609*, Sept. 25, 1904, a weak, undeveloped plant in flower and fruit, Herb. No. 52,281; Monteer, Shannon Co., *Bush 6134*, Aug. 8, 1910, a good, complete specimen just coming into flower, Herb. No. 52,282; Smithfield, Jasper Co., *Palmer*, Oct. 11, 1908, a good, full specimen with nearly all the fruit fallen off, Herb. No. 52,285; Kimmswick, Jefferson Co., *Wislizenus 108*, Aug. 23, 1885, a good middle portion of a plant without flowers or fruit, Herb. No. 52,287; Monteer, Shannon Co., *Bush 4897*, Oct. 10, 1907, a good, complete plant with nearly all the fruit fallen off, Herb. No. 52,283; St. Louis, St. Louis Co., *Glatfelter*, 1892, a good, complete plant just coming into flower, Herb. No. 52,284; Lake City, Jackson Co., *Mackenzie*, Aug. 9, 1896, a good, complete plant in flower and young fruit, Herb. No. 52,287; Kimmswick, Jefferson Co., *Wislizenus 108*, Aug. 23, 1885, evidently the upper part of sheet No. 52,289, in good flower and fruit, Herb. No. 52,288.

THE THELEPHORACEAE OF NORTH AMERICA. VII[1]

Septobasidium

EDWARD ANGUS BURT

Mycologist and Librarian to the Missouri Botanical Garden
Associate Professor in the Henry Shaw School of Botany of Washington University

SEPTOBASIDIUM

Septobasidium Patouillard, Jour. de Bot. **6**:61. *textf.* 1892; Essai Taxon. Hym. 7. 1900; Sacc. Syll. Fung. **11**:118. 1895; *ibid.* **14**:215. 1900; *ibid.* **16**:184. 1902; *ibid.* **17**:203. 1905; *ibid.* **21**:445. 1913. — *Jola* Möller, A., Bot. Mitth. a. d. Tropfen **8**, Protobasidiomyceten 22–29. *pl. 4. f. 4.* 1895; Engl. & Prantl, Nat. Pflanzenfam. **I.1****:84. 1897; Sacc. Syll. Fung. **14**:245. 1900.

The genus was founded upon *Septobasidium pedicellatum* Pat. and *Septobasidium velutinum* Pat.

Fructifications resupinate, effused, coriaceous, producing probasidia upon the hyphae at or near the hymenial surface; the probasidia remain attached to the hyphae and either produce at the apex a few-celled, hyaline, spore-bearing filament, or elongate, become septate, and differentiate into such a filament, usually termed a transversely septate basidium; spores simple, hyaline, even, borne one to each cell by the terminal cell and next lower cells.

The spores are apparently produced in succession upon the spore-bearing organ rather than simultaneously, for in only two instances have I observed two spores present at the same time upon the same organ; in these the two spores were very unequal in size. One sees a spore attached to the terminal cell more frequently than to lower cells but perhaps

Note.—Explanation in regard to the citation of specimens studied is given in Part VI, Ann. Mo. Bot. Gard. 3:208, footnote. The technical color terms used in this work are those of Ridgway, Color Standards and Nomenclature. Washington, D. C., 1912.

[1]Issued November 4, 1916.

because of the more favorable position of the terminal cell. I have frequently observed a spore attached to some one or other of the upper three cells of the spore-bearing organ but have seen such attachment to the fourth cell only in *S. castaneum,* although often noting on the fourth cell in some species a lateral protuberance similar to those to which spores were attached in the upper cells. The spore-bearing stage is apparently of very brief duration, judging by the few collections which show this stage well. Specimens are usually collected sterile or with probasidia. It is hoped that the record given as to the month when each of our species has been collected in spore-bearing condition may aid in securing more valuable specimens for study in the future.

Septobasidium is not one of the genera of the *Thelephoraceae,* for its spore-producing organs are not simple basidia. The genus is treated here merely for the convenience of students of the *Thelephoraceae,* as in the case of *Tremellodendron, Eichleriella,* and *Sebacina.* The coriaceous structure and resupinate habit of the species of *Septobasidium* are so similar to those of *Corticium* and other resupinate genera of the *Thelephoraceae* that examination by the microscope of sections of the fructification is necessary to distinguish an unfamiliar species of *Septobasidium* from *Corticium,* etc. Many of the known species of *Septobasidium* were originally published as Corticiums and Thelephoras, and it is probable that careful study of authentic specimens of the earlier species of these genera will lead to the transfer of additional species to *Septobasidium.* It is possible that some authors may have mistaken the pyriform to globose probasidia of species of *Septobasidium* for conidia and have published such species as *Hyphomycetes.* The probasidia may be distinguished from hyphomycetous spores by the former bodies remaining attached to the hyphae; the probasidia do not float about loose in preparations.

I am indebted to Dr. R. P. Burke for transmitting to me in fresh condition spore bearing material of three species of *Septobasidium.* Spore falls were obtained from this material for germination experiments and some material was

fixed and preserved for a cytological study of *Septobasidium* during spore production. Discussion of the systematic relationships of *Septobasidium* may well await the completion of such study.

The species of *Septobasidium* are tropical or subtropical. Extreme northern stations, based on specimens examined by the writer, are London, Ontario, Canada, and Madison, Wisconsin—both are stations for *S. pseudopedicellatum,* which is the most frequent species of the United States.

With regard to the biology of *Septobasidium,* several specimens of this genus—usually of *S. pseudopedicellatum*—have been noted by their respective collectors as occurring especially on plants badly affected by scale insects. Other specimens show scale insects numerous about the fructification and overrun by it. Petch [1] in a note on the biology of *Septobasidium* states that from examination of a long series of specimens, it has been determined that these fungi are parasitic on colonies of scale insects which they overgrow and destroy completely, and that these fungi live, not on secretions of the insects, but upon the insects themselves.

In addition to independent observations on the association of *Septobasidium* with scale insects, other facts tending to show an entomogenous adaptation of *Septobasidium* are the following:

(1) All species of *Septobasidium* known to the writer occur only on living branches or leaves, and in no instance has there been penetration by the fungus through the epidermis or bark into the living tissues of the substratum, or any injury or deformation or gall response by the branch or leaf.

(2) Spores are produced by *S. pseudopedicellatum,* in the region from North Carolina and Alabama to Porto Rico, in May when young colonies of the scale insects are forming. Mr. Seagle wrote to me that the old fructifications of *S. pseudopedicellatum* disappear from his apple trees in North Carolina in late spring and in early summer, and new fruc-

[1] Ann. Bot. 25:843. 1911.

tifications grow which become large by early winter. The collections which I have studied, made during fall and early winter, have been in vegetative rather than in fruiting stage.

On the other hand, some specimens of *Septobasidium* in herbaria have no scale insects on the portions of twigs bearing the fructifications of *Septobasidium*, but I can not say as to whether these fructifications made their start on clean twigs or on scattered scale insects which they have completely overgrown and destroyed.

KEY TO THE SPECIES

Fructification having the hymenial layer or membrane raised above the substratum and supported on scattered pillars composed of parallel hyphae close together side by side 1

Fructification having the hymenial layer supported on pillars but with the pillars less regular in form than in the above and composed of loosely interwoven and curving hyphae. Known from Cuba.....*10. S. cirratum*

Fructification lacking supporting hyphal pillars, with hyphae extending from substratum to the hymenial region without noteworthy consolidation 5

1. With erect or suberect paraphyses or hyphal branches at the surface of the hymenium 2

1. With surface of hymenium composed of longitudinally arranged and interwoven paraphyses or hyphal branches..... 3

1. Structure of surface of hymenium not published; probasidia 20×15–20μ, persistent at the base of the spore-bearing organs; spore-bearing organs horseshoe-shaped, 35×10μ. In Cuba .....*1. S. pedicellatum*

1. Structure of surface of hymenium not published; fructification black, shining, very thin. In Guadeloupe. .....*9. S. atratum*

2. Fructification ⅓–½ mm. thick; probasidia 12×7–9μ; spore-bearing organs 20–25×4½–5μ .....*2. S. Schweinitzii*

2. Fructification 1–1½ mm. thick; probasidia 26×11μ; spore-bearing organs hook-shaped, up to 50×8μ. In Mexico .....*3. S. tropicale*

2. Fructification 1–1½ mm. thick; probasidia 13–25×10–13μ; spore-bearing organs straight, up to 60×11μ; spores 13×5½μ. In Jamaica.... .....*8. S. jamaicaense*

2. Fructification not shining, velutinous, aniline-black, becoming fuscous in the herbarium; probasidia 15–20μ in diameter .....*7. S. Patouillardii*

3. Fructification glabrous, shining. 4

4. Varying from avellaneous and wood-brown to cinnamon-brown; probasidia 12–20×8–15μ; spores 17–22×4–5μ ....*4. S. pseudopedicellatum*

4. Vandyke brown when in vegetative condition, olive-brown when fertile; probasidia 11–15×9–10μ; spores 12×3–3½ μ .....*5. S. castaneum*

4. Olive-brown darkening to dark neutral gray; probasidia and spores unknown. In Nicaragua. .....*6. S. sublilacinum*

5. Fructification divided into many narrow, sinuous divisions, better shown toward the margin 6

5. Fructification not divided but with surface reticulated with obtuse veins; at first drab or Prout's brown then Chaetura-drab.....*13. S. retiforme*

5. Fructification neither divided nor veined 7

6. Plumbeous when bright colored, often smoke-gray or pallid mouse-gray, velutinous ..... *11. S. Langloisii*

6. Honey-yellow to old gold, velutinous ..... *12. S. frustulosum*

7. Hymenial crust glabrous, between mouse-gray and hair-brown; middle region spongy, lacunose; fructification 1½–2 mm. thick. In Cuba..... ..... *14. S. Spongia*

7. Fructification tomentose, between mouse-gray and hair-brown; probasidia 12–15μ in diameter; spores 12–15×5–6μ..... *15. S. fumigatum*

7. Fructification pubescent, white at first, pale olive-buff in the herbarium; probasidia 15–17μ in diameter; spores 15–20×5½–6μ. In California.... ..... *16. S. canescens*

7. Fructification velutinous, between lilac-gray and pallid smoke-gray; probasidia up to 9μ in diameter; spores 11–13×3½–4½μ. In Trinidad..... ..... *17. S. lilacinum*

1. Septobasidium pedicellatum Patouillard, Jour. de Bot. 6:61. *textf.* 1892.

Thelephora pedicellata of C. Wright's Cuban Exsiccati, but not of Schweinitz.

Type: in Museum of Paris.

Fructification with pillars or pedicels composed of hyphae which branch towards the upper end and pass into and support the hymenial crust; probasidia subglobose, 20 × 15–20μ, arising as lateral outgrowths near the ends of the final branches of the hyphae, producing from the apex a hyaline, cylindric, spore-bearing organ, 35 × 10μ, 2–3-septate, which becomes horseshoe-shaped, slightly constricted at the septa, and has a small protruberance on the convex side of each cell; no spores seen.

The above is a summary of the account by Patouillard,[1] of the structure of the specimen in the Museum of Paris, collected in Cuba by C. Wright and distributed by him in his Cuban exsiccati under the name *Thelephora pedicellata.* Wright made two collections in Cuba which were determined by Berkeley and Curtis[2] as *Thelephora pedicellata.* Since Patouillard omitted the data on the label of the specimen which he studied, I do not know now which of Wright's numbers is the type collection and have to defer a fuller consideration of this species to the supplement to my monograph.

[1] *Loc. cit.*
[2] Linn. Soc. Bot. Jour. 10:329. 1868.

2. S. Schweinitzii Burt, n. sp.

Thelephora pedicellata Schweinitz, Naturforsch. Ges. Leipzig Schrift. 1:108. *pl. 2. f. 3.* 1822; Fries, Elenchus Fung. 1:200. 1828; Epicr. 544. 1838; Sacc. Syll. Fung. 6:544. 1888. Not *Septobasidium pedicellatum* Pat.

Illustrations: Schweinitz, *loc. cit.*

Type: in Herb. Schweinitz.

Fructification resupinate, coriaceous, dry, not separable from the substratum, varying from drab and cinnamon-drab to wood-brown, the margin undulate, whitish; in structure 3-layered, with (1) a layer next to the substratum of densely interwoven, colored hyphae 3–3½μ in diameter, which form (2) a layer of erect hyphal pillars or pedicels each about 200–300μ long, 40–75μ in diameter, about 2 to a millimeter, and pass into and support at the outer end (3) the hymenial layer 120–200μ thick, composed of densely interwoven, colored hyphae 3–3½μ in diameter, of erect, flexuous, filiform, sparingly branched, hyaline paraphyses or hyphal branches about 1½μ in diameter, and, when in fertile stage, of hyaline, thin-walled, erect probasidia, pyriform to subglobose, 12 × 7–9μ in the type, borne on the colored hyphae; spores simple, hyaline, even, curved, 5 × 2½μ (as seen attached in the type but perhaps immature), borne singly at the apex of the terminal cell of a short filament 20–25 × 4½–5μ, about 4 cells long, curved to fish-hook-shaped in form, which develops from the probasidium.

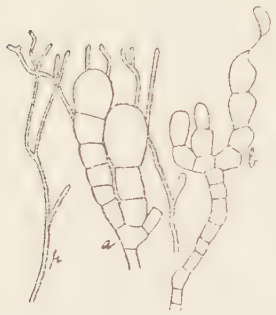


Fig. 1
S. Schweinitzii.
a, portion of hymenium showing paraphyses and two probasidia; *b*, spore-bearing organ and spore; *p*, paraphysis. × 640.

Fructifications 2 – several cm. long, 1 – several cm. broad, ⅓–½ mm. thick.

On living branches. North Carolina to Louisiana. Frequent in winter.

The above description is based on the Schweinitzian type and presents the characters of a rare species which has not been distinguished heretofore from the following *S. pseudo-pedicellatum,* a thicker, larger, common, and widely distributed species. *S. Schweinitzii* is characterized by its erect filiform paraphyses, curved to hook-shaped, spore-bearing organs, and small spores, although it is not certain that full-sized mature spores have yet been seen.

I refer to *S. Schweinitzii* a collection made by P. L. Ricker on *Persea,* in Georgia, during August, because this specimen has small probasidia, hook-shaped, few-celled, hyaline, spore-bearing organs, and spores 7 × 3½μ; but in this specimen only a few paraphyses are present, the probasidia and hook-shaped organs are at the very surface of the hymenium, and small, globose organs 5μ in diameter are occasionally present, borne laterally on the hyphae in the lower part of the hymenial layer. I have not studied with the microscope the Cuban specimen of *S. pedicellatum,* collected by C. Wright, one of the species upon the structure of which Patouillard founded the genus *Septobasidium.* He found this specimen to have probasidia and hook-shaped organs. Both probasidia and the hyaline organs are described as larger than they measure in the Schweinitzian type. In the Cuban specimen the probasidia are stated to be 20μ in diameter or 20 × 15μ, and the hook-shaped organs as 35 × 10μ, and the former persist full size, with the septate hook-shaped organs connected with them like a promycelium with its teleutospore. These differences indicate that the Cuban specimen belongs to a species distinct from *Thelephora pedicellata* Schw. It is necessary to substitute a new specific name for "pedicellata" in making the transfer of *Thelephora pedicellata* Schw. to *Septobasidium,* because there is already a valid *Septobasidium pedicellatum.*

Specimens examined:

North Carolina: *Schweinitz,* type (in Herb. Schw.).

Georgia: Bugaboo Island, Okeefenokee Swamp, *P. L. Ricker, 921.*

Louisiana: Gibson, *F. T. McLean*, comm. by P. Spaulding.

3. S. tropicale Burt, n. sp.

Type: in Mo. Bot. Gard. Herb. and in Farlow Herb.

Fructification resupinate, effused, coriaceous, dry, not separable from substratum, glabrous, not shining, avellaneous, the margin concolorous, squamulose-fimbriate, not closely adnate; in structure 3-layered, with (1) a layer next to the substratum of densely interwoven, concolorous, thick-walled hyphae 3–3½μ in diameter, which pass into and form (2) a layer of numerous erect, slender pillars about 40μ in diameter, 5 or 6 to the millimeter, whose hyphae spread apart at the outer end, branch, and form and support (3) the hymenial crust about 200μ thick, densely interwoven throughout, with the even, thick-walled, colored hyphae up to 6μ in diameter on the under side, more erect, paler, and about 2μ in diameter at the surface; probasidia terminal on the hyphae, hyaline or but slightly colored, pyriform, 26 × 11μ, at the surface of the hymenium; a spore partially imbedded in the hymenium is hyaline, simple, even, curved, 19 × 6μ, no others seen; fish-hook-shaped organs, such as probably bear the spores, are present in the surface of the hymenium, several-celled, up to 50 × 8μ, with prominent protuberances from cells on the convex side of the organ.

Fig. 2
S. tropicale.
a, probasidium; *b*, two spore-bearing organs; *s*, spore; *p*, paraphysis. × 640.

Fructification 4 cm. long, about 2 cm. broad, 1–1½ mm. thick.

On bark of living branches of *Quercus*. Mexico.

The distinctive characters of this species are avellaneous color, surface not shining, margin squamulose-fimbriate, not closely adnate as in the preceding species, and thicker hy-

menial crust not loosely interwoven on its under sides, probasidia terminal on the hyphae, and the large hook-shaped, presumably spore-bearing, organs of the upper surface. If these organs grow out from the probasidia, the probasidium must differentiate into the organ, for I have traced the curved organ back to the colored hyphal cells.

Specimens examined:

Mexico: locality not stated, *C. G. Pringle*, comm. by W. G. Farlow, 5 (in Mo. Bot. Gard. Herb., 44590).

4. S. pseudopedicellatum Burt, n. sp.

Thelephora pedicellata of most American authors but not of Schweinitz.

Type: in Mo. Bot. Gard. Herb.

Fructification resupinate, effused, coriaceous, dry, not separable from the substratum, varying from avellaneous and

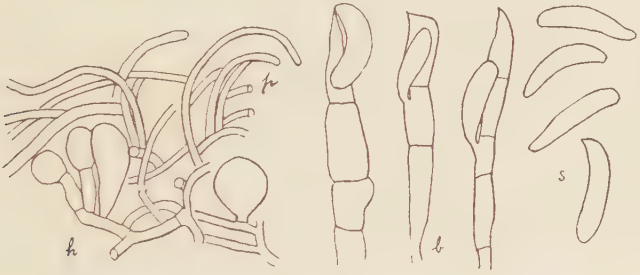


Fig. 3

S. pseudopedicellatum.

h, portion of hymenium showing the longitudinally interwoven hyphal ends or paraphyses and some probasidia; *b*, three spore-bearing organs; *s*, spores. × 640.

wood-brown to cinnamon-brown, the margin undulate, whitish; in structure three-layered, with (1) a layer next to the substratum of densely interwoven, thick-walled, slightly colored hyphae 3μ in diameter, which form (2) a layer of erect, hyphal pillars, or pedicels, each about 500μ long, 20–40μ in diameter, about 3–5 to a millimeter, whose hyphae spread apart at the upper end of the pillars, branch, and form and support (3) the hymenial crust about 300μ thick, with hyphae loosely interwoven near the pillars, 3–3½μ in

diameter, very dense at the outer surface with the hyphal branches or paraphyses 2μ in diameter, curved longitudinally along the surface and densely interwoven; erect probasidia nearly hyaline, rich in protoplasm, deeply staining, pyriform, 12–20 $\times$ 8–15μ, are borne laterally on the hyphae about 15μ below the surface of the hymenium; spores white in a spore collection, simple, even, curved, 17–22 $\times$ 4–5μ, are borne singly from each of the upper three cells (so far as observed) of a straight or flexuous, few-celled, hyaline organ up to 60 $\times$ 5–5½μ, which grows from the probasidium and protrudes above the surface of the hymenium.

Fructifications 2–15 cm. long, 1–8 cm. broad, 1–1½ mm. thick.

On small, living branches of apple, orange, oak, *Nyssa*, *Cornus*, *Liquidambar*, and also on orange leaves in one collection; sometimes, perhaps always, associated with scale insects. Canada to Florida and Louisiana and westward to Wisconsin; also in Cuba and Porto Rico. December to August; spores produced in the last of May.

S. pseudopedicellatum is the common *Septobasidium* of southeastern United States. It may be recognized by its brown, glabrous, shining, foliaceous crust which is raised and supported about a millimeter above the substratum on perpendicular, hyphal pillars which are as conspicuous as the rhizoids of a lichen. Old specimens may crack, break the hyphal pillars, and the hymenial crust curl outward so as to show the broken pillars attached to the under side. Sterile specimens of this species have been heretofore referred to *S. pedicellatum*, but a collection of fertile specimens received from Dr. R. P. Burke in May of the present year shows that our common species differs from *S. pedicellatum* by having large spores produced on a straight or but slightly curved, much larger, spore-bearing organ, paraphyses or hyphal branches at the surface of the hymenium curved and densely longitudinally interwoven, larger probasidia, and larger and thicker fructifications. Even in sterile condition the longitudinally interwoven paraphyses are sufficiently distinctive.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 12, under the name *Thelephora pedicellata.*

Canada: Ontario, London, *J. Dearness, 3396* (in Mo. Bot. Gard. Herb., 43802).

New Jersey: Newfield, *J. B. Ellis;* also from same locality in Ellis, N. Am. Fungi, 12.

Pennsylvania: Trexlertown, *W. Herbst,* comm. by Lloyd Herb., 2232.

North Carolina: Reepsville, *J. P. Seagle,* two collections, one of which was communicated by F. L. Stevens.

Florida: *W. W. Calkins;* Daytona, *R. Thaxter, 75a* (in Farlow Herb. and in Mo. Bot. Gard. Herb., 43894); Kissimmee, comm. by F. C. Wolf (in Mo. Bot. Gard. Herb., 44205); same locality, *B. E. Evans* (in Mo. Bot. Gard. Herb., 44403); Ft. Myers, *H. S. Fawcett* (in Fawcett Herb.); Gainesville, *H. E. Stevens,* comm. by E. Bartholomew, 40b (in Mo. Bot. Gard. Herb., 44212).

Alabama: *Peters, 75* (in Curtis Herb.); *F. S. Earle & C. F. Baker* (in Lloyd Herb., 3454); Auburn, *Alabama Biological Survey;* Montgomery, *R. P. Burke, 49,* and the type collection (in Mo. Bot. Gard. Herb., 10979, and 20659, type).

Louisiana: Gibson, *F. T. McLean,* comm. by P. Spaulding; St. Martinville, *A. B. Langlois,* three collections, two of which are (in Lloyd Herb., 2411, 3533).

Kentucky: comm. by A. H. Gilbert (in Mo. Bot. Gard. Herb., 44323); "in mountains," *P. Garman* (in Mo. Bot. Gard. Herb., 44302).

Wisconsin: Madison, *W. Trelease* (in Mo. Bot. Gard. Herb., 5164).

Cuba: Ceballos, *H. S. Fawcett, 10, 39* (in Mo. Bot. Gard. Herb., 15005, 15018); Isle of Pines, *H. S. Fawcett, 15* (in Mo. Bot. Gard. Herb., 15094).

Porto Rico: Mayaguez, *F. S. Earle, 79,* N. Y. Bot. Gard. Herb.

5. S. castaneum Burt, n. sp.

Type: in Mo. Bot. Gard. Herb.

Fructification resupinate, effused, coriaceous, dry, not separable from the substratum, glabrous, cracking in drying into pieces about 10 × 5 mm., olive-brown when fertile, Vandyke brown when in vegetative condition, the margin concolorous; in structure 3-layered, with (1) a layer next to substratum of opaque, concolorous hyphae 4μ in diameter, which form (2) a layer of pillared or spongy structure, in some places with pillars up to 150μ in diameter, about 1 mm. apart, and in other places with a spongy mass of obliquely ascending, interwoven hyphae similar to those of the pillars. This layer supports (3) the hymenial crust, sometimes stratose, with hyphae loosely interwoven on the under side, 3-4μ in diameter, very dense at the outer surface, with the hyphal branches or paraphyses 2μ in diameter, curved longitudinally along the surface and densely interwoven; erect probasidia slightly colored, rich in protoplasm, deeply staining, pyriform, 11–15 × 9–10μ, are borne laterally on the hyphae about 15μ below the surface of the hymenium; spores hyaline, simple, even, curved, 12 × 3–3½μ, borne singly from each of the upper four cells of a straight, few-celled, even-walled, clavate, hyaline organ 30–40 × 6μ, which grows from the probasidium and protrudes above the surface of the hymenium.

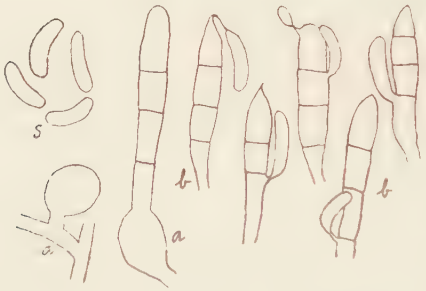


Fig. 4
S. castaneum.
a, two probasidia, one persistent at base of the spore-bearing organ which grows from it; *b*, six spore-bearing organs; *s*, spores. × 640.

Fructification 8-15 cm. long, wholly surrounding limbs 2½ cm. in diameter, 1–1½ mm. thick.

On living bark in swamp, Montgomery, Alabama. May and August—fertile in May.

This species is closely related to *S. pseudopedicellatum* but is more deeply colored, has more opaque hyphae, and smaller spores and spore-bearing organs. No lateral protuberances or papillae have been observed on the latter.

Specimens examined:

Alabama: Montgomery, *R. P. Burke*, two collections (in Mo. Bot. Gard. Herb., 20421, type, and 20693).

6. S. sublilacinum (Ellis & Ev.) Burt, n. comb.

Thelephora sublilacina Ellis & Ev. State Univ. Iowa, Lab. Nat. Sci. Bul. **13**:67. 1896; Sacc. Syll. Fung. **14**:214. 1900.

Type: in N. Y. Bot. Gard. Herb.

Fructification resupinate, effused, coriaceous, dry, not separable from the substratum, glabrous, shining, olive-brown, darkening to dark neutral gray; in structure 3-layered, with (1) a layer next to the substratum, 40–60μ thick, of closely crowded, longitudinally arranged hyphae concolorous with the fructification, 4–4½μ in diameter, which form (2) a layer of pillars 40–60μ in diameter, about 2–4 to a millimeter, whose hyphae spread apart at the outer end and form and support (3) the hymenial crust about 60μ thick, densely interwoven throughout, with even, thick-walled, concolorous hyphae 3–3½μ in diameter on the under side, 2μ in diameter, nearly hyaline, and densely, longitudinally interwoven at the surface; probasidia, spores or other organs not present in the type.

Fructification about ½ cm. in diameter, ¾ mm. thick.

On living branches. Nicaragua.

The type specimen of this species, when viewed from above, agrees so closely with the cotype of *S. Spongia* in color and habit that one is strongly disposed to regard the two specimens as of the same species. *S. sublilacinum* has, however, the coarser hyphae, a three-layered structure, and distinct pillars. It seems best to regard it as a distinct species, at least until fertile specimens define the species more definitely.

Specimens examined:

Nicaragua: *C. L. Smith, 108*, type (in N. Y. Bot. Gard. Herb.).

7. S. Patouillardii Burt, n. sp.

S. (very near) *Leprieurii* (Mont.) Patouillard, Soc. Myc. Fr. Bul. **16**:55. 1900.

Type: in Burt Herb.

Fructification resupinate, effused, coriaceous, dry, velutinous, aniline-black at first, becoming fuscous in the herbarium, the margin rather thick and determinate; in structure 200–400μ thick, with (1) next to the substratum a thin layer of loosely interwoven hyphae 3μ in diameter, buffy brown under the microscope, which form (2) a layer of hyphal pillars each about 30–50μ in diameter, 100–200μ long, about 3–4 to a millimeter, whose hyphae spread apart above and form (3) the interwoven hymenial layer containing some probasidia and with the surface composed of numerous erect, nearly straight, fuscous hyphal branches or paraphyses 2μ in diameter; probasidia hyaline, subglobose, 15–20μ in diameter, erect on short branches of the colored hyphae; no spores found; the only possible spore-bearing organ seen is 46 × 7½μ, acuminate at the apex.

Fig. 5
S. Patouillardii. *a*, two probasidia; *b*, spore-bearing organ; *p*, four paraphyses or hyphal ends. × 640.

Fructifications 2–3½ cm. long, 1–2 cm. broad, 200–400 mm. thick.

On living branches of ash, *Liquidambar*, and *Nyssa*. Florida to Louisiana. November to March; a January collection has a few probasidia.

This species may be recognized by its thin fructification resembling a piece of black velvet, slightly raised from the substratum on such short and slender pillars as to be barely visible without the aid of a lens. Patouillard determined this species for Mr. Langlois as very near to *S. Leprieurii*. Since *Corticium Leprieurii* was originally described as glabrous, shining, and chocolate colored, and since no specimens like ours have yet been collected in the region between Guiana and the United States, our specimens are probably a distinct species which should have a definite name.

Specimens examined:

Florida: Daytona, *R. Thaxter, 75b* (in Farlow Herb. and Mo. Bot. Gard. Herb., 43895).

Alabama: Auburn, *F. S. Earle & C. F. Baker,* also (in Mo. Bot. Gard. Herb., 5165).

Louisiana: St. Martinville, *A. B. Langlois, 3005,* determined by Patouillard as *S.* (very near) *Leprieurii;* Gibson, *F. T. McLean,* comm. by P. Spaulding, type—some fragments near a specimen of another species, but having probasidia, etc., as drawn, taken as the type because more mature than other collections cited.

8. **S. jamaicaense** Burt, n. sp.

Type: in Burt Herb. and N. Y. Bot. Gard. Herb.

Fructification resupinate, effused, coriaceous, spongy, dry, thick, bister, with the subiculum bone-brown; in structure with (1) next to the substratum a thin layer of interwoven hyphae which form (2) a layer of probably oblique, weak, very slender, crowded, hyphal pillars 12–20μ in diameter, up to 2000μ long, with hyphae even, 4–5μ in diameter, buffy brown under the microscope, diverging above to form (3) a spongy hymenial layer 300–400μ thick, with hyphae which rise obliquely, are loosely interwoven, and bear probasidia laterally at the outer surface of the layer and terminate in hyaline or subhyaline, curved branches or tips; probasidia hyaline, subglobose or pyriform, 13–25 $\times$ 10–13μ, quickly developing into hyaline, straight, few-celled, spore-bearing organs up to 60 $\times$ 11μ; spores simple, hyaline, slightly curved, 13 $\times$ 5½μ.

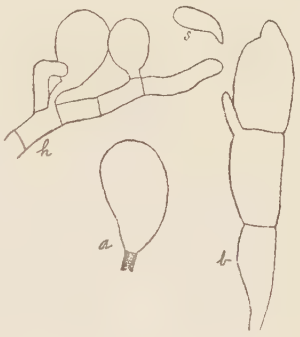


Fig. 6
S. jamaicaense.
h, hyphal end bearing two probasidia in the surface of the hymenium; *a*, probasidium; *b*, spore-bearing organ; *s*, spore. ×640.

Fructification larger than 6 cm. long, 2 cm. broad, 1–1½ mm. thick—fractured on all sides and not showing natural margin.

On bark. Base of John Crow Peak, altitude 5500 feet. Jamaica. April.

The type of this species has so thick and spongy a hymenial layer that I have tried to regard this specimen as the fertile stage of *S. Spongia*, but the well-developed layer of pillars is in the way of such reference and the hyphae are rather coarser than in *S. Spongia*.

Specimens examined:

Jamaica: John Crow Peak, *L. M. Underwood, 2439.*

9. **S. atratum** Patouillard, Soc. Myc. Fr. Bul. 16:181. 1900.

Type: location unknown.

Fructification resupinate, greatly extended, glabrous, shining, thin, with the margin fimbriate and incrusting; subiculum black, formed of rigid, erect, short bundles composed of hyphae but little branched, 4–5μ in diameter, with the wall thick and brown under the microscope; hymenial crust thin, fragile, continuous, glabrous, ombre noir, paler at the periphery; probasidia at first globose, 10–12μ in diameter, growing on the sides of erect hyphae of the hymenial crust a little below their ends; spores and spore-bearing organs not present.

On living trunk of *Eugenia Jambos*. Morne Gommier, near Galion, Guadeloupe. *P. Duss.*

In connection with the original description, Patouillard stated that *S. Spongia* is "epais, roux, spongieux, lacuneux," and that *S. atratum* is "tres mince, et noir." I have seen no specimens of *S. atratum* and base the above account of this species wholly on the original description.

10. **S. cirratum** Burt, n. sp.

Type: in Mo. Bot. Gard. Herb. and Humphrey Herb.

Fructification resupinate, effused, coriaceous, spongy, dry, cracked, velutinous, between Benzo-brown and brownish drab, with fuscous subiculum, the margin divided into narrow, sinuous divisions; in structure up to 700μ thick, with (1) next to the substratum a layer of interwoven hyphae, which form (2) a layer of pillars not uniform in diameter, composed of hyphae loosely interwoven, curled together,

suggestive of ringlets in sectional preparations, which support (3) the hymenial layer 200–300μ thick, with hyphae 2–2½μ in diameter, notably curved, branched, and loosely interwoven, olive-brown under the microscope, bearing in the lower part of the layer numerous concolorous, globose bodies 11μ in diameter, and toward the outer surface hyaline probasidia 11μ in diameter also, and terminating at the surface in fine, hyaline branches 1μ in diameter, with recurved or coiled tips; spores simple, hyaline, even, curved, 18 × 6μ; spore-bearing organs few-celled, straight, cylindric, about 35–40 × 7½μ, differentiating from the probasidia.

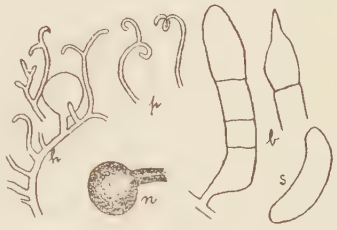


Fig. 7
S. cirratum.
h, portion of hymenium showing hypha bearing paraphyses and a probasidium; *b*, spore-bearing organs; *n*, colored body from deeper portion of hymenial layer; *p*, two paraphyses; *s*, spore. × 640.

Fructifications 5 cm. long, 1½ cm. broad.

On trunk of living hardwood tree near the base. Cuba. December. Seen but once by the collector.

S. cirratum has so nearly the color and habit of *Hypochnus fuscus* that it was a surprise to find the specimen a *Septobasidium*. The color and sinuously divided margin suggest *S. Langloisii*. The pillars composed of loosely interwoven and curving hyphae are unique and separate this species sharply from all our species of the *S. pedicellatum* group. The hyphae are too fine and too curving for *S. Spongia*.

Specimens examined:

Cuba: Omaja, *C. J. Humphrey, 2773* (in Mo. Bot. Gard. Herb., 15836).

11. S. Langloisii Patouillard, Soc. Myc. Fr. Bul. **16**:54. 1900.

Type: a portion in Burt Herb.

Fructification resupinate, effused, dry, velutinous, plumbeous when bright colored, but often smoke-gray or pallid mouse-gray, repeatedly divided into many narrow, sinuous

divisions which are more distinct towards the margin; in structure 200–250μ thick, with hyphae fuscous under the microscope, thick-walled, even, loosely interwoven from substratum to hymenium, densely interwoven in the hymenium and bearing hyaline, flexuous, suberect terminal branches or paraphyses and hyaline probasidia which are exceeded by the paraphyses; spores hyaline, simple, even, slightly curved, 15–21 × 5–7½μ, apparently produced singly at the apex of a nearly straight, 2–3-celled, spore-bearing organ into which the probasidium develops.

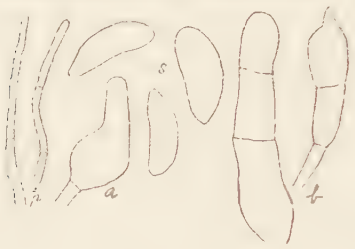


Fig. 8
S. Langloisii.
a, probasidium forming a spore-bearing organ; *b*, two spore-bearing organs; *p*, paraphyses; *s*, spores. × 640.

Fructification up to 5 cm. long, 2½ cm. broad, ¼ mm. thick.

On bark of living branches of *Crataegus, Carpinus,* and water oak. Florida to Louisiana and in Grenada. November to May.

This species resembles *S. frustulosum* in having the fructification divided into narrow sinuous divisions and differs from that species in being blue colored, verging into smoke-gray or paler in some specimens, instead of honey-yellow. The specimen from Grenada is thinner than those from other localities.

Specimens examined:

Exsiccati: Ravenel, Fungi Am., 450, under the name *Stereum pruinatum.*

Florida: Gainesville, *H. E. Stevens,* comm. by E. Bartholomew, 40a (in Mo. Bot. Gard. Herb., 44211); same locality, *Ravenel,* in Ravenel, Fungi Am., 450.

Alabama: Montgomery, *R. P. Burke,* 52 (in Mo. Bot. Gard. Herb., 9558).

Louisiana: St. Martinville, *A. B. Langlois, 2995,* type.

Grenada: Grand Etang, *R. Thaxter,* comm. by W. G. Farlow, a (in Mo. Bot. Gard. Herb., 43912).

12. S. frustulosum (Berk. & Curtis) Patouillard, Soc. Myc. Fr. Bul. **10**:79. *pl. 3. f. 4.* 1894.

Hymenochaete frustulosa Berk. & Curtis, Linn. Soc. Bot. Jour. **10**:334. 1868; Sacc. Syll. Fung. **6**:601. 1888.

Illustrations: Patouillard, *loc. cit.*

Type: type and cotype in Kew Herb. and Curtis Herb.

Fructification resupinate, effused, coriaceous, dry, velutinous, honey-yellow to old gold, repeatedly divided into many narrow, sinuous, reticulate divisions which are more distinct towards the margin; in structure about 600–700μ thick, 3-layered, with next to the substratum a broad layer, up to 200μ thick, with hyphae densely longitudinally arranged, 2μ in diameter, concolorous with the fructification, which ascend, without forming pillars, as (2) the loosely arranged middle layer, whose hyphae pass into and form (3) the hymenial crust which is finally very dense and compact in fully developed specimens, about 200μ thick, with hyphae concolorous, even, 1½–2μ in diameter, branching towards the surface into flexuous branches, or paraphyses, about 1μ in diameter, once or twice dichotomously branched and with tips curved or spirally coiled; probasidia borne laterally on the hyphae, hyaline, pyriform, 9 × 5½μ, becoming elongated and septate as a few-celled, spore-bearing organ, or producing directly a sterigma bearing one spore; spores hyaline, even, cylindric, nearly straight, 13–17 × 4–5μ.

Fig. 9

S. frustulosum.

a, probasidia; *b*, three spore-bearing organs; *n*, septate colored organ; *p*, paraphyses; *r*, probasidium bearing a spore; *s*, spores. × 640.

Fructifications up to 10 cm. long, 1–2 cm. broad, less than 1 mm. thick.

On bark of living limbs of frondose species. Mexico, West Indies, and Venezuela. February, March, November; spore-bearing in November.

This species is highly distinguished by honey-yellow color and the division of its fructification into narrow, sinuous, branched divisions, resembling those of the thallus of the lichens, *Physcia stellaris* and *P. obscura*. Spore-bearing organs are not abundant in the only fertile specimen which I have seen. They appear to become somewhat cork-screw-shaped, with no indication of bearing spores except on the terminal cell, but I was not certain on this point because the occasional attached spores were along the edge of thick sections where only the apex of the organ extended beyond the paraphyses. In two cases probasidia were bearing at the apex, each a body of the form and dimensions of a spore of this species. In the deeper portions of the fructifications brown, pyriform bodies of the same size and form as the probasidia are borne by the hyphae in the same location as the probasidia. These brown organs are often of the same dimensions as the spore-bearing organs, septate, and gorged with brown contents.

Specimens examined:

Exsiccati: Smith, Cent. Am. Fungi, 100, under the name *Thelephora retiformis.*

Mexico: Sanborn, Oaxaca, *C. R. Orcutt, 3334* (in Mo. Bot. Gard. Herb.).

Nicaragua: Castillo Viejo, *C. L. Smith*, in Smith, Cent. Am. Fungi, 100.

Cuba: *C. Wright, 244,* cotype (in Curtis Herb.).

Grenada: Grand Etang, *R. Thaxter*, comm. by W. G. Farlow, 11.

Venezuela: *Fendler, 279* (in Farlow Herb. and in Mo. Bot. Gard. Herb., 20411).

13. S. retiforme (Berk. & Curtis) Patouillard, Soc. Myc. Fr. Bul. **16**: 55. 1900.

Thelephora retiformis Berk. & Curtis, Linn. Soc. Bot. Jour. **10**:330. 1868; Sacc. Syll. Fung. **6**:544. 1888.

Type: type and cotype in Kew Herb. and Curtis Herb.

Fructification resupinate, effused, coriaceous, at first drab or Prout's brown, then Chaetura-drab, the hymenial surface reticulated with obtuse veins, pulverulent; in structure 700μ thick, with the hyphae colored, 3–4μ in diameter, short-celled, loosely interwoven or rising obliquely from substratum to hymenial surface and there densely interwoven longitudinally and bearing laterally brown, globose or pyriform bodies 13–15 $\times$ 10–13μ, and slightly colored probasidia of the same size and form; a single spore in the hymenial surface is hyaline, even, curved, 15 $\times$ 4μ; no spore-bearing organs found.

Fig. 10 S. retiforme. *a*, probasidium; *n*, colored organ; *s*, spore. $\times$ 640.

Fructification 1–4 cm. long, about 700μ thick.

On living branches of apple, pear, peach, *Carya*. District of Columbia to Louisiana and Cuba. November to February, producing probasidia in February.

S. retiforme resembles a small foliaceous lichen in habit. It may be distinguished from our other species by its drab to brown color and reticulately veined hymenial surface. The spore characters stated are uncertain for only one spore was seen.

Specimens examined:

Exsiccati: Ellis & Ev., N. Am. Fungi, 2604.

District of Columbia: Washington, comm. by Mrs. F. W. Patterson.

Georgia: Fort Valley, comm. by Mrs. F. W. Patterson.

Alabama: Forestdale, *C. C. Woodward,* comm. by J. B. Rorer; Abbeville, *S. T. Slaton* (also in Lloyd Herb., 3460, and in Mo. Bot. Gard. Herb., 5166).

Louisiana: St. Martinville, *A. B. Langlois, 2233.*

Cuba: *C. Wright, 288,* cotype (in Curtis Herb.).

14. S. Spongia (Berk. & Curtis) Patouillard, Soc. Myc. Fr. Bul. **16**:181. 1900.

Thelephora Spongia Berk. & Curtis, Linn. Soc. Bot. Jour. **10**:330. 1868; Sacc. Syll. Fung. **6**:542. 1888.

Type: type and cotype in Kew Herb. and Curtis Herb.

Fructification resupinate, effused, not separable from the substratum, dry, glabrous, shining, between mouse-gray and hair-brown, the margin strigose; in structure lacunose, spongy, about 1 mm. thick when dry, distending to 1½–2 mm. when moistened, with hyphae 3–3½μ in diameter, fuscous to clove-brown under the microscope, densely longitudinally arranged in masses along the substratum and rising obliquely so as to form a spongy structure with vacant spaces up to 800 × 500μ, united above into a continuous hymenial crust 40–80μ thick; probasidia, spores, and spore-bearing organs not present.

Fig. 11 S. Spongia. Vertical section of fructification showing spongy structure. × 9.

Fructification "spreading for many inches," 1½–2 mm. thick.

On bark of cacao trees. Cuba.

S. Spongia is distinguished from our other species in the group having a glabrous hymenial crust by the spongy, rather than pillared, structure of the middle region of the fructification. The surface of the cotype is infested with a colorless hyphomycete whose hyphae are densely crowded together and agglutinated; hence fertile specimens of this species will probably be browner than the original sterile, infested specimen.

Specimens examined:

Cuba: *C. Wright, 566,* cotype (in Curtis Herb., and a portion in Mo. Bot. Gard. Herb., 44592, by kindness of Dr. Farlow).

? Mexico: Monterey, Sierra Madre, *C. G. Pringle*, comm. by W. G. Farlow, 6 (in Mo. Bot. Gard. Herb., 44591).

15. S. fumigatum Burt, n. sp.

Type: in Mo. Bot. Gard. Herb. and Humphrey Herb.

Fructification resupinate, long and broadly effused, not separable from substratum, coriaceous, tomentose, between mouse-gray and hair-brown, rarely with surface pale, the margin thinning out and concolorous; in structure 800–1500μ thick, with hyphae buffy brown under the microscope, even, thick-walled, 4μ in diameter, loosely interwoven and ascend-

ing from substratum to hymenial region; in the hymenial region the hyphae become more densely interwoven and bear laterally numerous hyaline, subglobose probasidia 12–15μ in diameter, and terminate in small, curved or loosely coiled, colored branches—hardly paraphyses—2μ in diameter, which form the surface of the hymenium; spores simple, hyaline, even, slightly curved, 12–15 $\times$ 5–6μ, borne on the upper three cells of a few-celled, nearly straight, hyaline, spore-bearing organ 40–50 $\times$ 6–7½μ, into which the probasidium develops.

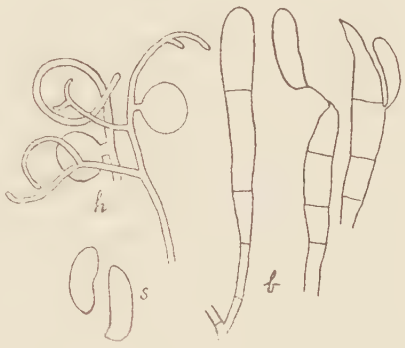


Fig. 12
S. fumigatum.
h, portion of hymenium showing hyphae bearing probasidia and terminating in curved and coiled ends; *b*, three spore-bearing organs; *s*, spores. $\times$ 640.

Up to 5 m. long, several cm. broad, ⅘–1½ mm. thick.

On trunks of living sapling of *Acer rubrum* and probably other species. South Carolina, Alabama, and Cuba. November to May; spores most numerous in May.

S. fumigatum has the general habit and color of *Hypochnus spongiosus* and is readily distinguishable among the North American species of *Septobasidium* by its mouse-gray color, tomentose surface, and felty structure of loosely interwoven hyphae which do not form pillars. It is only rarely that I have seen spores or evidences of spore production upon other than the terminal cell in this species.

Specimens examined:

South Carolina: Gourdin, *C. J. Humphrey, 2588*, type (in Mo. Bot. Gard. Herb., 43822).

Alabama: Montgomery, *R. P. Burke, 50*, and an *unnumbered collection* (in Mo. Bot. Gard. Herb., 11382, 20068).

Cuba: *C. Wright*, Fungi Cubenses Wrightiani, 838, comm. by W. G. Farlow (in Farlow Herb. and Mo. Bot. Gard. Herb., 43907).

16. S. canescens Burt, n. sp.

Type: in Mo. Bot. Gard. Herb.

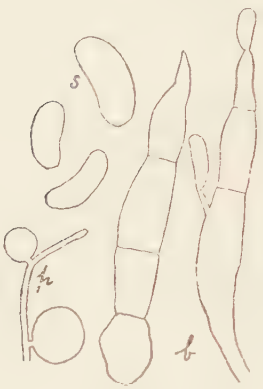


Fig. 13
S. canescens.
p, hypha in hymenial surface bearing probasidia; *b*, two spore-bearing organs; *s*, spores. × 640.

Fructification resupinate, effused, coriaceous, cottony, pubescent, white at first, pale olive-buff in the herbarium, the margin thinning out; in structure 500–900μ thick, with the hyphae hyaline, even, 4½μ in diameter, densely interwoven next to the substratum, suberect, or ascending obliquely and loosely interwoven to the hymenial surface and there bearing probasidia laterally among slightly curved hyphal branches about 2μ in diameter; probasidia hyaline, subglobose, 15–17μ in diameter, producing a few-celled organ 7½μ in diameter, up to 60μ long, which bears spores on its upper three cells; spores simple, hyaline, even, curved, 15–20 × 5½–6μ.

Fructifications about 2–4 cm. long, 1–1½ cm. broad, sometimes arranged more or less interruptedly for up to 25 cm. along the under side of limbs.

Associated fairly constantly with scale insects on small living branches of *Quercus* on a residence street, Pasadena, California. November to March.

S. canescens is characterized by its white to whitish color, cottony structure, and pubescent surface. Spores were observed attached to one or more of the upper three cells of the spore-bearing organ but with the terminal cell giving the most indication of spore production. I am indebted to Prof. H. S. Fawcett for the collection made in March to show this species in best fruiting condition.

Specimens examined:

California: Pasadena, *H. S. Fawcett*, comm. by W. A. Setchell (in Mo. Bot. Gard. Herb., 44037); same locality, *A. G. Smith*, comm. by H. S. Fawcett (in Mo. Bot. Gard. Herb., 44246).

17. S. lilacinum Burt, n. sp.

Type: in Farlow Herb. and Burt Herb.

Fructification resupinate, effused, coriaceous, dry, adnate, velutinous, between lilac-gray and pallid smoke-gray, the margin adnate, fimbriate; in structure 80–200μ thick, with hyphae thin-walled, 2–2½μ in diameter, somewhat colored near the substratum, ascending and interwoven and becoming hyaline towards the hymenium, finer, 1½μ in diameter, and bearing laterally probasidia, and extending beyond the probasidia and branching, with tips curved to form the velvety surface of the hymenium; probasidia hyaline, even, globose, up to 9μ in diameter; spores simple, hyaline, even, slightly curved, 11–13 × 3½–4½μ, borne on a few-celled, spore-bearing organ about 20–30 × 4–5μ, slightly curved at first.

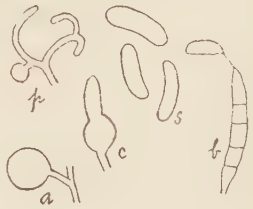


Fig. 14
S. lilacinum.
p, hyaline portion of hypha in hymenial surface bearing a probasidium; *a*, mature probasidium; *c*, probasidium with young spore-bearing organ; *b*, spore-bearing organ; *s*, spores. × 640.

Fructifications more than 6 cm. long, more than 1½ cm. wide.

On bark, Maravals, Trinidad, West Indies.

This species is characterized by its very thin, velvety fructification, pallid smoke-gray with a slight lilac tint, fine hyphae, and small probasidia, spore-bearing organs, and spores. The spore-bearing organs were slightly curved in all cases where spores were attached to them; in the sections some of these organs appeared strongly curved or hook-shaped but my preparations did not demonstrate this point positively, for the numerous curved hyphal branches were confusing.

Specimens examined:

Trinidad: Maravals, *R. Thaxter*, comm. by W. G. Farlow, 28, type.

(To be continued.)

CATALOGUE OF THE PLANTS OF JASPER COUNTY, MISSOURI

(Fernworts and Flowering Plants)

ERNEST J. PALMER
Collector for the Missouri Botanical Garden and the Arnold Arboretum of Harvard University

Introduction

This catalogue is based upon collections of plants made by the writer during the years from 1901 to 1913. The serial numbers following each species and variety listed refer to the plants collected by me, unless otherwise indicated; and the specimens are now deposited in the herbarium of the Missouri Botanical Garden. Many duplicates have been distributed to herbaria and collectors in various parts of this country and abroad. The nomenclature used is, with a few exceptions, that of the seventh edition of Gray's 'Manual.'

I believe that this is the first attempt at enumerating the native plants and those growing spontaneously in this part of Missouri. Local catalogues and floras have been published covering several other sections of the state—Jackson County and the vicinities of Louisiana, St. Louis, and Columbia. In 1886 Professor S. M. Tracy published a list of the plants then known to occur in the state, and in 1895 a list of the woody plants, prepared by Mr. B. F. Bush, was published by the State Horticultural Society. In these two works reference is made to plants of Jasper County. Two of the species mentioned by Professor Tracy as occurring in the county have not been found by the writer. These are *Castanea pumila*, said to have been collected by Professor Broadhead, and *Callirhoe involucrata*, which is recorded as having been collected by Letterman. The latter is probably a geographical error. In Mr. Bush's list 53 woody species are mentioned for Jasper County. All of these, with the exception of *Castanea pumila* and a few which have been relegated by changes in nomenclature and more recent study, have been confirmed.

But little botanical work had been done in the area prior to the beginning of the writer's collection. In connection with the work of the State Geological Survey some collections were made by Professor Garland C. Broadhead, who visited Jasper County. Mr. B. F. Bush had also done some collecting about Joplin and Carthage, and possibly others may have collected in the county; but it may be said to have been practically an unknown field, and that it has proved an interesting one is attested by the fact that since the beginning of the present century a number of eminent botanists have visited it. Among these is Dr. C. S. Sargent, the distinguished director of Arnold Arboretum and author of the 'Silva of North America,' who has made several trips through the county and has described about 40 new species of trees and shrubs, based wholly or in part upon Jasper County material. Most of these are of the genus *Crataegus*, the red haws, of which many interesting forms are found here. Mr. Alfred Rehder, of Arnold Arboretum, has also described a new variety of crabapple, *Malus ioensis*, var. *Palmeri*, and an elderberry, *Sambucus canadensis*, var. *submollis*, found in our area. *Rhexia latifolia* is a new species of the meadow-beauty collected in Jasper County and described by Mr. B. F. Bush. Mr. K. K. Mackenzie has recently published a description of *Geocarpon minimum*, a new and anomalous genus, at present known only to occur in our county. Several other plants are still subjects of study and may prove worthy of distinction.

In addition to the new species brought to light, a number of previously described plants, but not before collected or known in Missouri, and several that are not given as occurring in the range of Gray's 'Manual' have been found. Among these may be mentioned *Amphilophis Torreyanus*, *Setaria imberbis*, *Stenophyllus ciliatifolius*, *Scirpus carinatus*, *Carex arkansana*, *Crataegus spathulata*, var. *flavantha*, *Lathyrus pusillus*, *Vitis Linsecomii*, *Myriophyllum proserpinacoides*, *Daucus pusillus*, *Lamium purpureum*, *Hedeoma acinoides*, *Diapedium brachiatum*, *Chrysopsis pilosa*, *Erigeron tenuis*, *E. nudiflorus* and *Marshallia caespitosa*. Plants of

peculiar interest have been submitted to specialists on various groups, and local collections are cited in a number of recently published books and pamphlets, so that Jasper County can no longer be regarded as *terra incognita* in the botanical world.

It is not claimed, however, that the present catalogue is by any means complete or, indeed, anything but a foreword on the flora of the region. While every effort has been made to secure accuracy and to exclude doubtful and invalid species, it is scarcely to be hoped that no errors have crept in. In the present state of botanical science it is highly probable that changes in nomenclature and in the taxonomic interpretation of certain groups will take place for some years to come; and, no doubt, future investigators will take different views as to the validity of some species here listed. It is very likely, also, that there are a number of plants growing in the county that have so far escaped the attention of the collector. For obvious reasons the immediate vicinity of the writer's home, in the southwestern part of the county, has been most thoroughly explored. Excursions have been made as opportunity offered into other sections, and considerable collecting has been done in Jasper, Preston, and Sarcoxie Townships, but some portions of the county have received very little attention, especially the northeastern part, which is least accessible at present.

The flora of a region, moreover, is not a fixed quantity. Various causes, at present chiefly cultural, are responsible for the introduction of plants from other sections of the country and from foreign lands. On the other hand, as the land comes more and more under cultivation many of the rarer and less hardy species are likely to be exterminated, and some, no doubt, have already disappeared since the settlement of the country by Europeans.

The struggle for existence is perhaps as keen in the plant world as in any department of nature. Of the countless number of seeds and spores produced by some species, but a very small per cent find an opportunity to germinate, and a large proportion of the young seedlings are crowded or

starved out, fall a prey to enemies of the animal or plant world, to adverse weather conditions, or to other causes. Those that survive do so, often, by waging a fierce and successful battle with other species for the occupation of available ground. In this struggle, which has been going on for countless ages under changing conditions, forms have constantly been modified and those that could not adapt themselves to new environments have been exterminated and replaced by hardier and more fit races.

Deep buried in the shales of our coal measures are impressions of plants (principally ferns and other cryptogams) that flourished in the tropical marshes of a far-off period. Since then countless races of plants have come and gone, many of them leaving no trace, but under rare, favorable conditions fragments of some of them have been preserved; so that the paleobotanist, digging in the clays and shales of past geological ages, catches here and there a glimpse of those vanished floras, just as the archaeologist delves in the ashes of a ruined city or in the depths of some grass-grown mound in an effort to reconstruct at least an outline of the history of the past.

The layman, while recognizing the utility of forestry or the collection and study of plants of cultural, medicinal, or other economic value, is often puzzled to understand the object of purely scientific botany. To the scientist, however, regarding each plant as a wonderful living organism, marvelously adapted to its environment, with specific functions to perform, definite relationships with other species, and a history extending back into the remote past, even the commonest weed is an object of interest and worthy of study. And it is only by their systematic and critical study that a comprehensive knowledge of Nature's methods and the laws of life may be gained.

It is important, therefore, that the plants of all parts of the world should be collected, studied, and preserved; and I trust that the following catalogue and the collections upon which it is based, although dealing only with the plants

of a limited area, will be of some value and interest to future investigators.

I wish to express my sincere thanks to all of the botanists and friends who have aided and encouraged me in the collection and study of the plants of southwest Missouri. To Mr. B. F. Bush, whose unflagging interest in the work from its beginning has been one of the chief stimulants to its prosecution, I am under many obligations, both for the determination of plants during successive years when my time and botanical knowledge were both very limited, and for the contribution of literature and specimens for comparison. As the pleasant companion, too, of many botanical excursions I have had the benefit of his unequaled knowledge of plants in the field. I am also greatly indebted to Dr. C. S. Sargent for the interest he has taken in our woody flora and its investigation. Recognized as the highest authority on North American trees, his publication of several new species from Jasper County has made the region of considerable interest to the botanical world. Thanks are due to Dr. Ezra Brainerd for examining and revising the violets; to Mr. F. W. Pennell for checking the species of *Agalinis* and allied genera and for his key to this interesting group; to Mr. W. H. Blanchard for valuable notes on the *Rubi,* and to others. I also wish to make acknowledgments to Dr. George T. Moore, Director of the Missouri Botanical Garden, for affording the opportunity to publish this paper, and to Dr. J. M. Greenman, Curator of the Herbarium, for valuable suggestions and interest shown in the work.

Description of Jasper County

Jasper County, Missouri, is situated near the southwestern corner of the state, being in the western tier of counties bordering on Kansas, and but the third north from the Arkansas line. Its northern boundary is formed by Barton and Dade Counties, the eastern by Dade and Lawrence, and the southern by Newton County. In outline it is nearly rectangular. The width from north to south is about 21 miles, and length

from east to west about 32 miles, the area being 632 square miles. The center of the county is approximately in latitude 37°10′ north, and longitude 94°20′ west of Greenwich. The elevation ranges from about 825 feet in the valley of Spring River near the western boundary to about 1175 feet on the highest hills in the southeastern part.

Topographically, the area is a dissected plain, with hills of low elevation, situated on the western slope of the Ozark dome. Most of the country may be described as an upland prairie with considerable broken, hilly ground bordering the streams, especially along Center Creek in the southern portion. Through this plateau the larger streams have carved valleys of varying widths, in the alluvial plains of which they meander from bluff to bluff. These valleys, originally heavily wooded with deciduous forests of oak, maple, ash, walnut and many other trees, are now nearly all cleared and under agriculture. Remnants of the low forests remain only here and there, but considerable areas of the rocky, broken uplands in the southern part are still covered with a virgin or second growth of somewhat stunted timber, in which oaks and hickories predominate.

The drainage system is simple, consisting of Spring River and its tributaries, flowing in the main from east to west. The most important of these are North Fork and Dry Fork on the north, and, to the south, Center Creek with its affluents—Jenkins Creek, Jones Creek, and Grove Creek—and Turkey Creek, which flows directly into Spring River a little beyond the Kansas boundary. Spring River and the creeks to the south are perennial streams fed by many springs. North Fork and Dry Fork are intermittent but flow throughout the greater portion of the year. There are no large lakes or other natural bodies of water, but a few bayous or old channels along Spring River and Center Creek afford a habitat for some aquatic plants.

With the exception of the alluvial valleys the soil is largely residual, resulting from the decomposition of the underlying rocks. In consequence, there is a rather close correlation between the geology and local plant distribution.

The geological formations represented are the Mississippian series, or Subcarboniferous, and the Pennsylvanian series, or Coal Measures. The Mississippian occupies much the greater portion of the area. The rocks of this series consist mainly of heavily bedded, semi-crystalline limestones interbedded with lenses of chert, which in places predominates over the limestone. As the silicious rocks are much less soluble than the calcareous beds, large deposits of angular chert fragments, more or less imbedded in red iron-stained clay, occur locally where the higher beds of limestone have been removed by erosion. The horizontal strata of limestone form bold escarpments and bluffs along the river valleys and sometimes outcrop through the mantle of residuum on slopes and high hills.

The Pennsylvanian formations, consisting of shales and sandstones of the Cherokee group, occupy the northwestern corner of the county, covering portions of Jasper and Twin Groves and the greater part of Preston and Duval Townships. Small isolated areas to the southward are too limited in extent to have much influence upon the flora. The rocks of this series, being soft and friable, give rise to a distinct topography with gentle slopes and low hills, through which flow sluggish intermittent streams. The influence upon the flora of these differences in soil and physical features is quite marked.

An interesting geological feature is the occurrence of water-worn river gravels covering some of the higher elevations through the south-central portion of the county. These deposits, which have been referred to the Lafayette Gravel of Tertiary age, are of very limited extent, but will be mentioned in connection with the flora.

In so limited an area climatic influences are, of course, essentially uniform, and the variations in altitude are not sufficiently great to affect plant life except indirectly. Over the bulk of the area, underlaid by Mississippian rocks, the factors which determine plant associations and restrict the range of certain species are moisture, shade, and the local

character of soil and surface rock. The timbered portion may be divided into low woods, bluffs, upland woods, and copses or thickets.

The low woods are confined to the alluvial valleys of the larger streams. The lower parts are subject to overflow and farther back from the streams a second terrace or bottom is often found. Characteristic species of the low woods are *Carya illinoensis*, *Salix longifolia*, *S. nigra*, *Betula nigra*, *Quercus macrocarpa*, *Benzoin melissaefolium*, *Platanus occidentalis*, *Acer saccharinum*, *Adelia acuminata*, *Aristolochia tomentosa*, *Onoclea sensibilis*, *Cinna arundinacea*, *Carex tribuloides*, *C. crus-corvi*, *C. Grayii*, var. *hispidula*, *Commelina hirtella*, *Saururus cernuus*, *Laportea canadensis*, *Pilea pumila*, *Polygonum virginianum*, *Iresine paniculata*, *Iodanthus pinnatifidus*, *Arabis dentata*, *Ranunculus septentrionalis*, *Lycopus rubellus*, *Diapedium brachiatum*, *Galium Vaillantii*, *Heracleum lanatum*, *Sicyos angulatus*, *Lobelia cardinalis*, *Eupatorium coelestinum*, and *Aster Tradescanti*. Some of these species extend their range through the second bottoms to the bases of the bluffs or into low prairies where moisture is abundant, and mingled with them are many plants more common in the latter situations.

The alluvial valleys are usually bounded by cliffs, rarely more than 50 or 60 feet in height, along the slopes and bases of which is found a very characteristic and varied flora, especially where the face of the cliff has a north or east exposure. These bluffs are usually well wooded, affording shade and protection for herbaceous species; they are supplied with abundant seepage water, have accumulations of soil washed from the hills above and are enriched by the leaf mould and vegetable humus of ages. On account of their inaccessibility and little value for utilitarian purposes they have remained more nearly in a primitive state than any other portion of the area. Here are found many plants common to the northeastern states, most of the ferns and orchids, and some of our most beautiful and delicate wild flowers. The list of plants peculiar to this zone is a long one but the fol-

lowing may be mentioned as typical: *Ulmus fulva, Acer saccharum, Ostrya virginiana, Asimina triloba, Staphylea trifolia, Adiantum pedatum, Camptosorus rhizophyllus, Polystichum acrostichoides, Cystopteris bulbifera, C. fragilis, Botrychium virginianum, Brachyelytrum erectum, Sphenopholis pallens, Poa Wolfii, Carex sparganioides, C. laxiflora,* var. *blanda, C. oligocarpa, Arisaema triphyllum, Tradescantia virginiana, Erythronium americanum, E. albidum, Smilacina racemosa, S. stellata, Polygonatum commutatum, Trillium sessile, Cypripedium parviflorum, Corallorrhiza odontorhiza, Liparis liliifolia, Asarum canadense, Ranunculus recurvatus, Aquilegia coccinea, Cimicifuga racemosa, Caulophyllum thalictroides, Sanguinea Dilleniana, Dicentra Cucullaria, Corydalis flavula, Arabis laevigata, Sedum Nevii, Euphorbia heterophylla, Erigenia bulbosa, Osmorhiza Claytoni, O. longistylis, Campanula americana, Solidago arguta, Polymnia uvedalia,* and *Senecio obovatus,* var. *rotundus.*

Where the bluffs have a western or southern exposure and are less shaded a somewhat different type of vegetation appears. Here are found *Sapindus Drummondi, Cheilanthes Feei, Notholaena dealbata, Asplenium parvulum, Festuca nutans, Bromus purgans, Uniola latifolia, Camassia esculenta, Commelina crispa, Arabis hirsuta, Heuchera hirsuticaulis, Hypericum cistifolium, Scutellaria cordifolia, Onosmodium hispidissimum,* and *Lonicera dioica.*

At the extreme edge of the bluff above may be found *Amelanchier canadensis, Celtis georgiana, Crataegus obscura, Rhus trilobata,* and many of the herbaceous species common to the limestone barrens and dry woods.

Above the escarpment a belt is usually occupied by the dry, rocky woods, more or less broken by ravines, up which the rich wood species extend. Characteristic species here are *Carya alba, C. megacarpa, C. ovalis* and its variety *obcordata, Quercus stellata, Q. velutina* and variety *missouriensis, Q. marilandica, Cornus florida, Fraxinus americana, Ceanothus americanus, Panicum linearifolium, P. huachucae* and the variety *silvicola, Danthonia spicata, Gymnopogon*

ambiguus, Cyperus ovularis, Carex retroflexa, C. varia with variety *colorata, Luzula campestris,* var. *bulbosa, Spiranthes gracilis, Anychia polygonoides, Lespedeza virginica, L. Stuvei, L. hirta, Desmodium rotundifolium, D. bracteosum, Ascyrum hypericoides, Lechea villosa, L. tenuifolia, Viola pedata,* var. *lineariloba, Asclepias quadrifolia, Tephrosia virginiana, Monarda Bradburiana, Scutellaria incana, Aureolaria grandiflora, Agalinis tenuifolia, Hieracium Gronovii, H. scabrum, Solidago nemoralis, S. radula, S. petiolaris, S. Wardii, Aster patens, A. anomalus, A. azureus, A. turbinellus, A. linariifolius, Erigeron pulchellus,* and *Parthenium integrifolium.*

The most extensive and notable floral division is perhaps that of the upland prairies, and here the plants of the plains are the most conspicuous feature. Among prairie plants may be mentioned *Andropogon scoparius, A. furcatus, Sorghastrum avenaceum, Sporobolus asper, Cyperus acuminatus, Erythronium mesochoreum, Silene regia, Ranunculus fascicularis, Draba brachycarpa, Baptisia bracteata, B. australis, Petalostemum purpureum, Astragalus distortus, A. mexicanus, Desmodium illinoense, D. canadense, Lespedeza capitata* and variety *sericea, Strophostyles pauciflora, Linum medium, Euphorbia corollata, Oenothera maricata, O. biennis, Gaura Pitcheri, Polytaenia Nuttallii, Dodecatheon Meadia, Apocynum cannabinum, A. pubescens, Sabatia campestris, Asclepias tuberosa, A. verticillata, A. stenophylla, Acerates floridana, A. viridiflora, Phlox pilosa, Lithospermum angustifolium, Salvia Pitcheri, Agalinis fasciculata, A. tenuifolia, Houstonia minima, Specularia biflora, Prenanthes aspera, Hieracium longipilum, Vernonia crinita, Eupatorium altissimum, Liatris scariosa, L. pycnostachya, Aster salicifolius, Silphium laciniatum, S. integrifolium, Parthenium repens, Brauneria pallida, Helianthus scaberrimus, H. grosseserratus, H. mollis, Coreopsis grandiflora, C. palmata, Helenium autumnale, Cacalia tuberosa,* and *Cirsium altissimum.*

Copses and thickets occupy swales or slopes bordering the dry woods, on the one hand, and the upland prairie, on the other. While containing many of the plants of the surround-

ing regions the thickets have quite a distinctive flora, for here are found many shrubs and vines and some herbaceous plants that seldom or never grow in other situations. Among the small trees are many species of *Crataegus* and *Prunus*, and a long list of sedges and grasses occur. *Ulmus americana* is frequently the only large tree along upland branches, and elsewhere large specimens of *Populus deltoides* occur far out on flat prairies. Along the branches and in wet depressions usually grow *Salix Wardi, Amorpha fruticosa, Cornus Amomum, Penthorum sedoides, Hibiscus incanus, H. militaris, Cicuta maculata, Asclepias incarnata, Lobelia siphilitica,* and *Lycopus americanus.* Occupying somewhat drier situations are *Celtis occidentalis, Corylus americana, C. rostrata, Ribes missouriensis, Opulaster intermedius, Malus ioensis,* var. *Palmeri, Rubus occidentalis, R. Andrewsianus, R. canadensis, Rosa setigera, Prunus hortulana, P. Munsoniana, Cercis canadensis, Zanthoxylum americanum, Ptelea trifoliata, Rhus glabra, R. copallina, Evonymus atropurpureus, Rhamnus lanceolata, Cornus asperifolia, C. Baileyi, Viburnum prunifolium, V. rufidulum, Symphoricarpos orbiculatus, Smilax rotundifolia, S. hispida, Clematis Pitcheri, Menispermum canadense, Cocculus carolinus, Celastrus scandens, Vitis cinerea, Ampelopsis cordata, Geum vernum, G. canadense, Cassia Medsgeri, Phaseolus polystachyus, Strophostyles umbellata, Galactia volubilis, Vincetoxicum carolinense, V. Baldwinianum, Scrophularia marilandica, Dasistoma macrophylla, Galium pilosum, G. circaezans, Triosteum perfoliatum, Rudbeckia triloba, Verbesina virginica,* and *Cacalia atriplicifolia.*

In addition to the area, of which the main floral zones are outlined above, there are several rather distinct regions in which a close association between the underlying geological features and the present plant life is clearly traceable.

The most extensive of these is the sand hill region or Barton upland, underlaid by Pennsylvanian strata, in the northwestern part of the county. This section is largely high prairie which slopes down to, and is limited by, the valleys

of North Fork on the east and of Spring River on the south. Seepage springs and small, sluggish streams give a wet and somewhat swampy character to some portions. The soil is, for the most part, a sandy loam, with large blocks of sandstone on the surface of some of the higher hills and sandstone and shale outcropping along streams. Peculiar to this area, so far as has been observed within the county, are *Andropogon ternarius, Panicum scoparium, Setaria imberbis, Festuca Shortii, Eleocharis orata, Rynchospora cymosa, Scleria ciliata, Scirpus carinatus, Carex arkansana, Juncus monostichus, J. effusus, J. polycephalus, J. robustus, Polygonum sagittatum, Froelichia gracilis, Geocarpon minimum, Ranunculus oblongifolius, Rhexia latifolia, Proserpinaca palustris, Centunculus minimus, Chrysopsis pilosa*, and *Cirsium discolor*. Other species, more or less characteristic of this region but which have also been found elsewhere in the county, are *Quercus palustris, Cyperus esculentus, Fimbristylis castanea*, var. *puberula, Rynchospora glomerata, Scleria triglomerata, Carex umbellata, C. stipata, Luzula campestris*, var. *bulbosa, Polygonum tenue, Anemone caroliniana, Polygala sanguinea, P. incarnata, Crotonopsis linearis, Viola pedata*, var. *linariloba, V. sagittata, Monarda mollis, Linaria canadensis, Castilleja coccinea*, and *Marshallia caespitosa*. Of the above list, *Froelichia gracilis* and *Chrysopsis pilosa* have only been found on an isolated sandstone hill at the state line, near Smithfield, and *Scirpus carinatus* in lower ground near the same place.

A region of much more limited extent, but with a distinct flora, is situated in the valley of Turkey Creek, two miles northwest of Joplin, where the Grand Falls chert of the Mississippian series outcrops. The surface of the chert is irregular, with hummocks and basin-like depressions of various sizes. Many of the latter contain thin layers of soil washed from the higher ground and in wet times are filled with rain-water, which, since the rock where unfractured is impermeable, is retained until evaporated by the sun. The superabundance of moisture in rainy seasons and extreme

dryness at other times, together with an almost total absence of shade, the sparsity of soil and other ecological factors, produces peculiar conditions clearly reflected in the flora, which is partly hydrophytic but mainly xerophytic and succulent. Some of the characteristic species are *Cheilanthes lanosa, Selaginella rupestris, Leptochloa fascicularis, Cyperus aristatus, Digitaria filiformis, Aristida basiramea, Allium mutabile, Polygonum tenue, Talinum parviflorum, T. calycinum, Portulaca pilosa, Selenia aurea, Sedum Nuttallianum, S. pulchellum, Lathyrus pusillus, Crotonopsis linearis, Opuntia macrorhiza, Spermolepis echinata, Linaria canadensis, Specularia leptocarpa, Coreopsis tinctoria,* and *Krigia occidentalis.* The chert formation is much more extensively exposed a few miles to the south along Shoal Creek in Newton County, where all of the above and several other peculiar species are found.[1]

Somewhat similar, though quite distinct, are the limestone barrens found at several places in the county, where horizontal strata of the Mississippian series appear on the surface. All of these are of quite limited extent but support a characteristic flora. Some of the best-marked localities are the following: one mile north of Jasper, on south side of Coon Creek; two miles southwest of Neck City, along a small branch; one mile north of Carterville, on south side of Center Creek and along a branch south and east of Carterville and Webb City. Typical plants of these limestone barrens are *Ophioglossum Engelmanni, Sporobolus pilosus, Sphenopholis obtusata, Bouteloua curtipendula, Cyperus aristatus, Camassia esculenta, Oxybaphus albidus, Arenaria patula, Talinum calycinum, Portulaca pilosa, Draba cuneifolia, Corydalis montana, Sedum pulchellum, Acalypha gracilens, Tragia ramosa, Euphorbia missouriensis, Malvastrum angustum, Mentzelia oligosperma, Opuntia humifusa, Chaerophyllum texanum, Heliotropium tenellum, Isanthus brachiatus, Galium virgatum, Aster oblongifolius,* var. *rigidulus,* and *Artemisia mexicana.*

[1]See Palmer, E. J. Flora of the Grand Falls chert barrens. Acad. Sci. St. Louis, Trans. 19:97–112. 1910.

Some high hills near Prosperity and Duenweg, partly covered with deposits of Lafayette gravel, have a somewhat characteristic flora, although few, if any, of the species are peculiar to them. Antennarias are a conspicuous feature of the spring vegetation, and it is probable that one or more undescribed species occur here. Other plants that may be mentioned are *Panicum depauperatum*, *P. Werneri*, *Carex umbellata*, *C. Meadii*, *Fimbristylis castanea*, var. *puberula*, *Stipa spartea*, *Viola pedata*, var. *lineariloba* of which a white form is frequent, *V. sagittata*, *Lithospermum canescens*, *Senecio plattensis*, and *Marshallia caespitosa*.

Introduced plants, while quite numerous, do not as yet form a large percentage of the flora, but their invasion is steadily increasing, especially in the western part of the county where many railroads enter. Grasses and common weeds form the bulk of these emigrants. These flourish largely in waste places and in cultivated ground, and their distribution has little definite relationship to the native plants. Among species of recent introduction a few show a tendency to become wide-spread. *Lespedeza striata* is becoming common in dry rocky woods, and the white-flowered sweet clover, *Melilotus alba*, is frequently found along roadsides and railroads. The sand burr, *Solanum rostratum*, has in recent years become quite common in ballast or waste ground, but it shows little tendency to spread beyond such situations. *Helenium tenuifolium* is beginning to appear along railroads and bids fair to become a nuisance. *Perilla frutescens* is established at several stations and, judging by the rapidity with which it has spread in the bottoms of many Ozark streams, is likely to become common. Perhaps most pernicious of all is the Johnson grass, *Sorghum halepense*, which is established in a number of low fields.

From a study of the above and the following list it will be seen that the flora of Jasper County is a diverse and composite one. The plants of the near plains are perhaps the dominant element and the most striking feature, but mingled with them are a number of types of the northeastern states,

others characteristic of the Ozark or southeastern mountain region, quite an element of southwestern species and some that are distinctly southern. That the central Mississippi Valley is the meeting ground of these various floras is well known, and Jasper County, through its diversity of soil and topography, fairly epitomizes, and is typical of, the region.

Catalogue of Species

POLYPODIACEAE

Notholaena dealbata (Pursh) Kunze. *640, 641, 642, 2992.*

Adiantum pedatum L. *634, 635, 636, 1319.*

Pteris aquilina, var. pseudocaudata Clute. *643, 644, 645.*

Cheilanthes lanosa (Michx.) Watt. *1321, 2376.*

Cheilanthes Feei Moore. *649, 650, 651, 1827, 2991.*

Pellaea atropurpurea (L.) Link. *637, 638, 639, 2985, 2989, 3085.*

Asplenium parvulum Mart. & Gal. *628, 629, 2993, 3168.*

Asplenium platyneuron (L.) Oakes. *631, 632, 758, 2481, 2019, 3152.*

Asplenium platyneuron, var. serratum (Miller) BSP. *2085.*

Camptosorus rhizophyllus (L.) Link. *625, 626, 1543.*

Polystichum acrostichoides (Michx.) Schott. *622, 623, 2961.*

Cystopteris bulbifera (L.) Bernh. *647, 2964, 2977, 3169.*

This species is sometimes difficult to distinguish from *Cystopteris fragilis,* as it seldom produces the characteristic fleshy bulblets in our area, and the fronds seldom exceed 20 cm. in length, but it differs from the next species in being broader at the base, thinner, and with segments less decurrent along the rachis. It is found along moist shaded ledges of limestone bluffs. *C. fragilis* seems to prefer rich banks and shaded hillsides.

Cystopteris fragilis (L.) Bernh. *646, 2327, 2978, 3018, 3255, 3388.*

Woodsia obtusa (Spreng.) Torr. *619, 620, 2216, 2328, 2480, 3059.*

Onoclea sensibilis L. *1320, 2111, 2976, 3156, 3697.*

OPHIOGLOSSACEAE

Ophioglossum Engelmanni Prantl. *2044, 2942, 3358.*

Engelmann's adder's-tongue has been found in thin soil of limestone barrens near Carterville and in similar situations along North Fork of Spring River near Neck City. At the latter station several large colonies were growing.

Botrychium virginianum (L.) Sw. *616, 617, 618, 2030, 2947, 3154, 3698, 3359.*

Botrychium obliquum Muhl. *3153.*

Rare and local. A few plants were found in rich hillside woods at a station along Center Creek, about four miles southeast of Carthage, September 11, 1910.

EQUISETACEAE

Equisetum arvense L. *890, 2544.*

Equisetum hyemale L. *958.*

SELAGINELLACEAE

Selaginella rupestris (L.) Spring. *1322.*

PINACEAE

Juniperus virginiana L. *887, 1919.*

The red cedar is rare in our county. A number of small trees were noted on rocky uplands north of Spring River between Carthage and Alba; some large stumps were found along a bluff of North Fork between Jasper and Preston, but no living plants were left at this station. Young plants are occasionally found in woods throughout, the seeds probably having been carried by birds from planted trees.

TYPHACEAE

Typha latifolia L. *2306.*

SPARGANIACEAE

Sparganum americanum Nutt. *780, 3158, 3159.*

NAJADACEAE

Potamogeton obtusifolius Mertens & Koch. *3184.*

Potamogeton foliosus Raf. *3251.*

Potamogeton dimorphus Raf. *1257, 2514, 3879.*

Potamogeton pectinatus L. *2204, 3251.*

ALISMACEAE

Sagittaria latifolia Willd. *460, 809, 1080.*

Sagittaria ambigua J. G. Sm. *2130, 3061, 3727.*
Sagittaria graminea Michx. *3677.*
Lophotocarpus calycinus (Engelm.) J. G. Sm. *471, 3748.*
Alisma Plantago-aquatica L. *343, 2183, 2783, 3786.*

HYDROCHARITACEAE

Elodea canadensis Michx. *3765.*

GRAMINEAE

Tripsacum dactyloides L. *1372, 3411, 3762.*
Andropogon scoparius Michx. *220.*
Andropogon virginicus L. *1007.*
Andropogon Elliottii Chapman. *2808.*
Andropogon ternarius Michx. *3268.*
Andropogon furcatus Muhl. *678, 2591, 2838, 3080, 3143, 3183.*
Andropogon chrysocomus Nash. *217, 678.*
Amphilophis Torreyanus (Steud.) Nash.
Sorghastrum nutans (L.) Nash. *279.*
Sorghum halepense (L.) Pers. *997.*
Sorghum vulgare L. *637.*
Digitaria filiformis (L.) Koeler. *2810, 3116.*
Digitaria humifusa Pers. *2815.*
Digitaria sanguinalis (L.) Scop. *607, 3823.*
Leptoloma cognatum (Schultes) Chase. *978, 1403, 3112.*
Paspalum mucronatum Muhl. *1389, 1490.*
Paspalum dissectum L. *968, 969, 1393, 3227, 3878.*
Paspalum Muhlenbergii Nash. *1117, 1390, 2341, 3066, 3161, 2289.*
Paspalum laeve Michx. *1118.*
Paspalum angustifolium LeConte. *777, 3067.*
Paspalum praelongum Nash. *966, 1439, 3140, 3228.*
Paspalum floridanum Michx. *1391, 1392, 3170.*
Paspalum laeviglume Scribn. *967, 2334.*
Paspalum glabratum (Engelm.) Mohr. *965, 970.*
Panicum capillare L. *227, 1402, 2550, 3090, 3096.*
Panicum Gattingeri Nash. *3204.*
Panicum flexile (Gattinger) Scribn. *786, 838, 843, 1119, 1400, 3089.*

PANICUM PHILADELPHICUM Bernh. *815, 3115, 2447.*
PANICUM DICHOTOMIFLORUM Michx. *2647, 3119, 3225.*
PANICUM VIRGATUM L. *216, 975, 977, 992, 2439, 2533.*
PANICUM AGROSTOIDES Spreng. *972, 1367, 3025, 3174.*
PANICUM ANCEPS Michx. *606, 764, 1406, 3048.*
PANICUM DEPAUPERATUM Muhl. *847, 1881, 1953.*
PANICUM PERLONGUM Nash. *594, 2156, 3372.*
PANICUM LINEARIFOLIUM Scribn. *2236, 3382, 3354* (*1555* of *B. F. Bush*).
PANICUM WERNERI Scribn. *2426.*
PANICUM HUACHUCAE Ashe. *749, 846, 2047, 2101, 3753.*
PANICUM HUACHUCAE, var. SILVICOLA Hitchc. & Chase. *1394, 1399, 2017, 3732, 3746, 3756.*
PANICUM SUBVILLOSUM Ashe. *3398, 3402.*
PANICUM TENNESSEENSE Ashe. *596, 974, 3409, 3761, 3714.*
PANICUM PRAECOCIUS Hitchc. & Chase. *2144.*
PANICUM SPHAEROCARPON Ell. *247, 850, 1398, 2154, 2507, 3808.*
PANICUM SCRIBNERIANUM Nash. *223, 590, 2046, 2014, 2160, 2157, 3397, 3713.*
PANICUM SCOPARIUM Lam. *611, 1401, 2293.*
PANICUM CLANDESTINUM L. *971, 1404, 1395.*
PANICUM PUBIFOLIUM Nash. *1562.*
PANICUM LATIFOLIUM L. *597, 849, 1405, 740, 2106, 2966.*
PANICUM HELLERI Nash. *973, 1857.*
PANICUM LINDHEIMERI Nash. *748, 1396, 2179, 2276, 3037.*
ECHINOCHLOA CRUSGALLI (L.) Beauv. *246, 976, 2570, 3486, 3477.*
SETARIA IMBERBIS R. & S. *2438, 2471, 3050, 3422, 3034.*
SETARIA GLAUCA (L.) Beauv. *2347, 3071.*
SETARIA VIRIDIS (L.) Beauv. *606, 3076.*
SETARIA ITALICA (L.) Beauv. *2551.*
SETARIA ITALICA, var. GERMANICA (Mill.) Richter. *991.*
CENCHRUS TRIBULOIDES L. *763.*
LEERSIA VIRGINICA Willd. *1000, 1561, 1381, 3207.*
LEERSIA ORYZOIDES (L.) Sw. *1001, 1370, 1557, 2682.*
PHALARIS CAROLINIANA Walt. *221.*
PHALARIS CANARIENSIS L. *3784.*
STIPA SPARTEA Trin. *2159.*

Aristida dichotoma Michx. *1387, 1494, 3488.*
Aristida basiramea Engelm. *2854.*
Aristida gracilis Ell. *3217.*
Aristida intermedia Scribn. & Ball. *1121.*
Aristida oligantha Michx. *814, 1385, 2527.*
Aristida purpurascens Poir. *1002, 1386.*
Aristida fasciculata Torr. *4361.*
Muhlenbergia sobolifera (Muhl.) Trin. *856, 1375, 2529, 2546.*
Muhlenbergia tenuiflora (Willd.) BSP. *218, 2734.*
Muhlenbergia sylvatica Torr. *3187.*
Muhlenbergia mexicana (L.) Trin. *1388, 2686, 2797, 3463, 3467, 3475.*
Muhlenbergia Schreberi J. F. Gmel. *1376, 2646, 2984.*
Muhlenbergia diffusa Schreb. *988, 990, 3488.*
Muhlenbergia capillaris (Lam.) Trin. *2828.*
Brachyelytrum erectum (Schreb.) Beauv. *2459, 2545, 3196.*
Phleum pratense L. *995, 2127.*
Alopecurus geniculatus L. *225, 1826.*
Sporobolus canovirens Nash. *1005.*
Sporobolus asper (Michx.) Kunth. *2811, 3117, 3134, 3215, 3252, 3216.*
Sporobolus vaginiflorus (Torr.) Wood. *2796, 3118.*
Sporobolus neglectus Nash. *2843.*
Sporobolus pilosus Vasey. *987, 3133.*
Sporobolus Drummondii (Trin.) Vasey. *3479, 3485.*
Agrostis alba L. *860, 2223.*
Agrostis Elliottiana Schultes. *1377, 2941.*
Agrostis hyemalis (Walt.) BSP. *2288, 2517.*
Agrostis perennans (Walt.) Tuckerm. *835, 854, 979, 993, 2410, 3008, 3416.*
Agrostis intermedia Scribn. *3101.*
Cinna arundinacea L. *857, 998, 1368, 2492.*
Sphenopholis obtusata (Michx.) Scribn. *2444, 2987.*
Sphenopholis pallens (Spreng.) Scribn. *2948, 2962, 3363.*
Koeleria cristata (L.) Pers. *222, 2970.*
Danthonia spicata (L.) Beauv. *1364, 2224.*
Spartina Michauxiana Hitchc. *1369, 1495, 2573.*

CYNODON DACTYLON (L.) Pers. *2450, 3501.*
SCHEDONNARDUS PANICULATUS (Nutt.) Trel. *2497.*
GYMNOPOGON AMBIGUUS (Michx.) BSP. *1371, 1373, 2829.*
BOUTELOUA CURTIPENDULA (Michx.) Torr. *215, 2340, 2359, 2612.*
ELEUSINE INDICA Gaertn. *605.*
LEPTOCHLOA ATTENUATA Nutt. *2577, 2733, 3094, 3911.*
LEPTOCHLOA MUCRONATA (Michx.) Kunth. *2569.*
LEPTOCHLOA FASCICULARIS (Lam.) Gray. *2509.*
TRIDENS STRICTUS (Nutt.) Nash. *1374, 2627, 2812, 3065.*
TRIDENS FLAVUS (L.) Hitchc. *2621, 3195.*
ERAGROSTIS HYPNOIDES (Lam.) BSP. *855, 1378, 1379.*
ERAGROSTIS CAPILLARIS (L.) Nees. *231, 994, 1380, 2267, 2448, 2853, 2836, 3028, 3230.*
ERAGROSTIS FRANKII (Fisch, Mey. & Lall.) Steud. *2818.*
ERAGROSTIS PILOSA (L.) Beauv. *980, 2456, 2489, 3008.*
ERAGROSTIS PURSHII Schrad. *980, 3138, 3279.*
ERAGROSTIS MEGASTACHYA (Koeler) Link. *229, 600.*
ERAGROSTIS PECTINACEA (Michx.) Steud. *842, 996, 1146, 2449, 2852.*
MELICA MUTICA Walt. *861, 1809, 3769.*
MELICA NITENS Nutt. *859.*
DIARRHENA DIANDRA (Michx.) Wood. *3803.*
UNIOLA LATIFOLIA Michx. *226, 603, 1373.*
DACTYLIS GLOMERATA L. *598.*
POA ANNUA L. *576, 986.*
POA CHAPMANIANA Scribn. *554, 2911, 3369.*
POA COMPRESSA L. *2451.*
POA PRATENSIS L. *985, 1383.*
POA SYLVESTRIS Gray. *987, 1382, 1384, 1836.*
POA WOLFII Scribn. *853, 3364.*
GLYCERIA NERVATA (Willd.) Trin. *2068, 2273, 3744, 3780.*
FESTUCA OCTOFLORA Walt. *224, 613, 1882, 3664, 2687.*
FESTUCA ELATIOR L. *2369, 2408, 2495, 3077.*
FESTUCA NUTANS Spreng. *858, 999, 2240, 2322, 2413, 3656, 3693, 3384.*
FESTUCA SHORTII Kunth. *2246, 2429, 2431, 2432.*

Bromus secalinus L. *589.*
Bromus purgans L. *1142, 1365, 1366, 2239.*
Bromus commutatus Schrad. *3413, 3721.*
Bromus arvensis L. *2979.*
Agropyron Smithii Rydb. *2590.*
Agropyron repens (L.) Beauv. *3418.*
Triticum vulgare L. *2090.*
Hordeum jubatum L. *2222.*
Hordeum pusillum Nutt. *984.*
Elymus virginicus L. *228, 2477, 3024.*
Elymus glabriflorus (Vasey) Scribn. & Ball. *983, 1143.*
Elymus canadensis L. *588, 2333.*
Elymus glaucus Buckley. *3045.*
Elymus brachystachys Scribn. & Ball. *982, 2453, 2534.*
Hystrix patula Moench. *612, 981, 3781.*

CYPERACEAE

Cyperus rivularis Kunth. *1047, 2754.*
Cyperus aristatus Rottb. *884, 2520, 3088, 3280.*
Cyperus acuminatus Torr. & Hook. *242, 2264, 3229.*
Cyperus pseudovegatus Steud. *234, 1048.*
Cyperus esculentus L. *2482, 3141, 3447, 3476.*
Cyperus esculentus, var. angustispicatus Boeckl. *2601.*
Cyperus speciosus Vahl. *3224.*
Cyperus strigosus L. *245, 3213, 3796, 3462.*
Cyperus strigosus, var. robustior Kunth. *241, 3142.*
Cyperus strigosus, var. compositus Britton. *2712, 3245.*
Cyperus strigosus, var. capitatus Boeckl. *1049.*
Cyperus Lancastriensis Porter. *1493, 2476, 2531.*
Cyperus ovularis (Michx.) Torr. *232, 2366, 3794.*
Cyperus filiculmis Vahl. *233, 2265, 3238.*
Cyperus Bushii Britton. *2946.*
Kyllinga pumila Michx. *788, 3834.*
Eleocharis ovata (Roth) R. & S. *1362.*
Eleocharis obtusa (Willd.) Schultes. *690, 1363, 3090, 3678, 3750.*
Eleocharis Engelmanni Steud. *189, 1563, 3631, 3770.*

Eleocharis palustris (L.) R. & S. *3379, 2168, 2169, 3718.*
Eleocharis palustris, var. glaucescens (Willd.) Gray. *1817.*
Eleocharis tenuis (Willd.) Schultes. *765, 2013, 3444.*
Eleocharis acuminata (Muhl.) Nees. *3630.*
Eleocharis lanceolata Fernald. *2292.*
Eleocharis macrostachya Britton. *2149, 2564.*
Eleocharis acicularis (L.) R. & S. *2587, 3421, 3426, 3719.*
Stenophyllus capillaris (L.) Britton. *3029, 3265, 3278.*
Stenophyllus ciliatifolius (L.) Mohr. *776, 1361, 3212.*
Fimbristylis castanea, var. puberula (Michx.) Britton. *595, 742, 1963, 2012, 2123, 2296, 3624.*
Fimbristylis laxa Vahl. *1046, 3120, 3264.*
Fimbristylis autumnalis (L.) R. & S. *1360.*
Scirpus americanus Pers. *274, 677, 2496.*

This species of rush frequently grows about the mines, in wet "mineral sand," and in water pumped from mines which is strongly impregnated with iron sulphide and is fatal to many forms of plant life.

Scirpus validus Vahl. *608, 2167.*
Scirpus atrovirens Muhl. *2128, 2202.*
Scirpus lineatus Michx. *593, 2091.*
Scirpus carinatus Gray. *3642.*
Rynchospora cymosa Ell. *2440, 2473, 3038, 3051.*
Rynchospora glomerata (L.) Vahl. *1044, 1045, 2434, 3038a, 3056.*
Scleria triglomerata Michx. *900, 2155, 2474.*
Scleria ciliata Michx. *2472, 2471, 3033.*
Carex scoparia Schkuhr. *2291.*
Carex tribuloides Wahlenb. *864, 2187, 3740, 3772.*
Carex mirabilis Dewey. *3771.*
Carex hormathodes Fernald. *3374.*
Carex hormathodes, var. invisa (W. Boott) Fernald. *3662.*
Carex Bicknellii Britton. *1958, 2284, 3674, 3716, 3724.*
Carex festucacea Schkuhr. *555, 869, 874, 2150, 3370, 3582, 3653, 3760.*
Carex rosea Schkuhr. *871.*
Carex rosea, var. radiata Dewey. *3385, 3635, 3692.*

Carex retroflexa Muhl. *876, 1354, 1861, 3353.*
Carex austrina (Small) Mack. *1353, 2225, 3652, 3684, 3751.*
Carex arkansana Bailey. *3723.*
Carex cephalophora Muhl. *880, 3633.*
Carex Leavenworthii Dewey. *867, 872, 1358, 1778, 1851.*
Carex sparganioides Muhl. *1356, 3691.*
Carex vulpinoidea Michx. *1052, 2067, 2126, 3417.*
Carex conjuncta Boott. *877, 3696, 3787.*
Carex annectens Bicknell. *3759.*
Carex stipata Muhl. *873, 1962, 2174, 2442, 3679.*
Carex crus-corvi Shuttlw. *863, 2197.*
Carex Emoryi Dewey. *1910, 3706.*
Carex hirsuta Willd. *1593, 1865, 2078, 2206, 3720, 3675, 3807.*
Carex Bushii Mack. *3389, 878, 1865, 3676.*
Carex caroliniana Schwein. *2912, 3743.*
Carex aggregata Mack. *2207.*
Carex Davisii Schwein. & Torr. *1352, 1852, 3403, 3699.*
Carex Shortiana Dewey. *870, 2193, 3375, 3670.*
Carex umbellata Schkuhr. *238, 3589, 3625.*
Carex varia Muhl. *1357, 1666.*
Carex varia, var. colorata Bailey. *578, 3520, 3602.*
Carex Meadii Dewey. *239, 553, 1763, 3372, 3627, 3638.*
Carex ptychocarpa Steud. *2266.*
Carex laxiflora Lam. *599, 866, 868.*
Carex laxiflora, var. patulifolia (Dewey) Carey. *1880.*
Carex laxiflora, var. varians Bailey. *3366.*
Carex laxiflora, var. blanda (Dewey) Boott. *3694.*
Carex oligocarpa Schkuhr. *1953, 3364.*
Carex grisea Wahlenb. *882, 1050, 3700, 3773.*
Carex grisea, var. rigida Bailey. *1818.*
Carex lanuginosa Michx. *1874, 3741.*
Carex riparia W. Curtis. *1820, 1909, 2293.*
Carex squarrosa L. *875, 3403, 3735.*
Carex Frankii Kunth. *602, 1051, 2192.*
Carex lurida Wahlenb. *2135, 3054.*
Carex lupulina Muhl. *1050, 3017.*
Carex lupulina, var. pedunculata Dewey. *864, 2191, 2305, 3626, 3768.*

Carex Grayii, var. hispidula Gray. *604, 1359, 2023, 2196, 3739.*
Carex oklahomensis Mack. *3405.*

This species was described by Kenneth K. Mackenzie[1] giving reference to No. 3405 of this collection.

ARACEAE

Arisaema triphyllum (L.) Schott. *548, 687.*
Arisaema Dracontium (L.) Schott. *519.*
Acorus Calamus L. *1716, 2505.*

LEMNACEAE

Spirodela polyrhiza (L.) Schleid. *1247, 2200.*

COMMELINACEAE

Tradescantia brevicaulis Raf. *298.*

I have grown hybrids of this and the following species in my garden.

Tradescantia reflexa Raf. *299, 657, 1954, 3365.*

A form of this species with sheaths and leaves copiously hirsute has been found in rocky woods.

Tradescantia virginiana L. *1289.*
Commelina virginica L. *300, 2380.*
Commelina hirtella Vahl. *1092, 1288, 1485.*
Commelina nudiflora L. *1287, 1486.*
Commelina crispa Wooton. *2242.*
Commelina communis L. *2311.*

PONTEDERIACEAE

Pontederia cordata L. *1087.*
Heteranthera limosa (Sw.) Willd. *829, 2623.*

JUNCACEAE

Juncus tenuis Willd. *610, 750.*
Juncus interior Wiegand. *591, 2118, 2446.*
Juncus monostichus Bartlett. *2285.*
Juncus effusus L. *2283.*
Juncus polycephalus Michx. *2300, 3430.*
Juncus nodosus L. *609.*
Juncus Torreyi Coville. *601, 2504.*

[1]Torreya 14:125–127. 1914.

JUNCUS BRACHYCARPUS Engelm. *237, 2103, 2119, 2151, 2212, 2286, 2299, 2484.*
JUNCUS DIFFUSISSIMUS Buckley. *236, 2211, 3757.*
JUNCUS ROBUSTUS (Engelm.) Coville. *2301.*
JUNCUS MARGINATUS Rostk. *240, 751, 2275.*
JUNCUS MARGINATUS, var. SETOSUS Coville. *243, 2122.*
JUNCUS ARISTULATUS Michx. *1408, 2117, 2294.*
LUZULA CAMPESTRIS, var. BULBOSA A. Wood. *577, 1407, 1604, 3644.*

LILIACEAE

MELANTHIUM VIRGINICUM L. *2182.*
ALLIUM CANADENSE L. *521, 2099.*
ALLIUM MUTABILE Michx. *2114, 2274.*
ALLIUM SATIVUM L. *2129, 2503.*
NOTHOSCORDUM BIVALVE (L.) Britton. *294.*
LILIUM CANADENSE L. *2354, 2891.*
ERYTHRONIUM AMERICANUM Ker. *292, 1623.*
ERYTHRONIUM ALBIDUM Nutt. *1613, 1617.*
ERYTHRONIUM MESOCHOREUM Knerr. *293, 1596, 1605.*
CAMASSIA ESCULENTA (Ker.) Robinson. *291.*

CONVALLARIACEAE

SMILACINA RACEMOSA (L.) Desf. *737.*
SMILACINA STELLATA (L.) Desf. *556, 736.*
POLYGONATUM COMMUTATUM (R. & S.) Dietr. *735.*
TRILLIUM SESSILE L. *295.*
ASPARAGUS OFFICINALIS L. *2312.*
SMILAX HERBACEA L. *473.*
SMILAX ECIRRHATA (Engelm.) Wats. *487, 736.*
SMILAX ROTUNDIFOLIA L. *55, 735, 892.*
SMILAX BONA-NOX L. *340, 718.*

Plants apparently belonging to this species are not uncommon, but I have not collected it in fruit in the county.

SMILAX HISPIDA Muhl. *1074, 3850.*

DIOSCOREACEAE

DIOSCOREA PANICULATA Michx. *527.*

Names and determinations of H. H. Bartlett[1] are followed for this species and succeeding variety.

DIOSCOREA PANICULATA, var. GLABRIFOLIA Bartlett. *832.*

AMARYLLIDACEAE

HYPOXIS HIRSUTA (L.) Coville. *694, 695.*

IRIDACEAE

IRIS VERSICOLOR L. *883, 2112.*
BELAMCANDA CHINENSIS (L.) DC. *1095.*
SISYRINCHIUM CAMPESTRE Bicknell. *119, 560, 686.*
SISYRINCHIUM GRAMINEUM Curtis. *120, 121, 122.*

ORCHIDACEAE

CYPRIPEDIUM PARVIFLORUM Salisb. *895, 1526, 1860.*
POGONIA TRIANTHOPHORA (Sw.) BSP. *3102.*
SPIRANTHES GRACILIS (Bigel.) Beck. *797, 3122.*
SPIRANTHES VERNALIS Engelm. & Gray. *408, 2566.*
SPIRANTHES CERNUA (L.) Richard. *337, 826, 1484, 3225, 3263.*
CORALLORRHIZA ODONTORHIZA Nutt. *1267, 1914.*
LIPARIS LILIIFOLIA (L.) Richard. *2171.*

PIPERACEAE

SAURURUS CERNUUS L. *793, 1131.*

SALICACEAE

SALIX NIGRA Marsh. *921, 2002.*
SALIX LONGIPIPES Anders. *917, 919.*
SALIX ALBA, var. VITELLINA (L.) Koch. *1246, 2606.*
SALIX LONGIFOLIA Muhl. *920.*
SALIX HUMILIS Marsh. *386, 918, 1611.*
SALIX CORDATA, var. MYRICOIDES (Muhl.) Carey. *1875, 2843.*
POPULUS ALBA L. *390.*
POPULUS DELTOIDES, var. MISSOURIENSIS Henry. *22, 2100, 3321, 3361, 3380, 3504, 3598.*
POPULUS NIGRA L. *1878.*

[1]U. S. Dept. Agr., Bul. 189. 1910.

JUGLANDACEAE

JUGLANS NIGRA L. *960, 2071.*

CARYA PECAN C. K. Schneider. *1313.*

The pecan is not abundant in this section. Trees are found occasionally along Spring River and the lower part of Center Creek, near Carl Junction and Smithfield.

CARYA OVATA (Mill.) K. Koch. *456, 1314, 1904.*

CARYA ALBA (L.) K. Koch. *65, 1072.*

CARYA ALBA, var. FICOIDES Sarg. *3493.*

This variety of the mocker-nut, with large pear-shaped fruit, was described by Professor Sargent[1] from a tree growing in Mt. Hope Cemetery, Webb City. It has been noted in other parts of southwest Missouri.

CARYA OVALIS (Wang.) Sarg. *14, 25, 818, 1073, 1127, 2809, 3493.*

CARYA OVALIS, var. OBCORDATA Sarg.

CARYA CORDIFORMIS (Wang.) K. Koch. *26, 1126.*

CARYA CORDIFORMIS, var. LATIFOLIA Sarg.

CARYA LACINIOSA (Michx. f.) Loud. *4031.*

The large-fruited, shell-bark hickory is rare in our area, a few trees only having been noted along Spring River, a few miles west of Carthage.

CARYA ARKANSANA Sargent.

BETULACEAE

CORYLUS AMERICANA Walt. *891, 926.*

CORYLUS ROSTRATA Ait. *3455.*

OSTRYA VIRGINIANA (Mill.) K. Koch. *32, 380, 3522.*

BETULA NIGRA L. *925, 1544.*

FAGACEAE

QUERCUS ALBA L. *81, 705.*

QUERCUS STELLATA Wang. *25, 964, 2145.*

QUERCUS MACROCARPA Michx. *74, 1537.*

QUERCUS MUHLENBERGII Engelm. *26, 963, 1071, 1139, 3854.*

QUERCUS RUBRA L. *79.*

QUERCUS PALUSTRIS Muench. *901, 1275, 1514, 1901, 902.*

QUERCUS SCHNECKII Britton. *5, 78, 903, 962.*

QUERCUS VELUTINA Lam. *4, 27, 53, 1276.*

[1]Trees and shrubs 2:206. 1913.

QUERCUS VELUTINA, var. MISSOURIENSIS Sarg. *1125.*
QUERCUS MARILANDICA Muench. *19, 24, 32, 704.*

ULMACEAE

ULMUS FULVA Michx. *90, 376, 3424.*
ULMUS AMERICANA L. *83, 379, 385, 1636, 3536.*
CELTIS OCCIDENTALIS L. *1130, 1538, 2675.*
CELTIS MISSISSIPPIENSIS Bosc. *47, 1279, 1280, 1277, 1551, 2082, 1278, 3659.*
CELTIS GEORGIANA Small. *1182, 1494, 875, 3489.*

MORACEAE

CANNABIS SATIVA L. *902.*
HUMULUS LUPULUS L. *410, 1258.*
HUMULUS JAPONICUS Sieb. & Zucc. *3799.*
MACLURA POMIFERA (Raf.) Schneider. *1129, 3303.*
MORUS RUBRA L. *54, 3355.*
MORUS ALBA L. *901.*
MORUS NIGRA L. *3729.*

URTICACEAE

LAPORTEA CANADENSIS (L.) Gaud. *468.*
PILEA PUMILA (L.) Gray. *339, 3256.*
BOEHMERIA CYLINDRICA (L.) Sw. *421, 830, 876, 3446.*
PARIETARIA PENNSYLVANICA Muhl. *346.*

SANTALACEAE

COMANDRA UMBELLATA (L.) Nutt. *582, 3607, 3626.*
COMANDRA PALLIDA A. DC. *2460, 3774.*

ARISTOLOCHIACEAE

ASARUM CANADENSE L. *693, 922.*
ARISTOLOCHIA TOMENTOSA Sims. *29, 948.*
ARISTOLOCHIA SERPENTARIA L. *1552, 1915, 1986, 2227, 2422, 2259.*

POLYGONACEAE

RUMEX CRISPUS L. *151, 152.*
RUMEX ALTISSIMUS Wood. *148, 149.*
RUMEX VERTICILLATUS L. *1282, 2314.*
RUMEX OBTUSIFOLIUS L. *153, 537, 2689.*
RUMEX ACETOSELLA L. *150, 1079.*

Polygonum aviculare L. *252, 447, 482.*
Polygonum erectum L. *894.*
Polygonum ramosissimum Michx. *441, 1540.*
Polygonum tenue Michx. *2775, 2847.*
Polygonum lapathifolium L. *250.*
Polygonum Muhlenbergii (Meisn.) Wats. *2335.*
Polygonum pennsylvanicum L. *249, 442, 443, 444, 3882.*
Polygonum longistylum Small. *1078.*
Polygonum Hydropiper L. *251.*
Polygonum acre HBK. *445.*
Polygonum acre, var. leptostachyum Meisn. *154, 2720.*
Polygonum orientale L. *2593.*
Polygonum Persicaria L. *155, 446.*
Polygonum hydropiperoides Michx. *464, 2287, 2332, 2438, 2779.*
Polygonum virginianum L. *156, 3210.*
Polygonum sagittatum L. *790, 3053, 3261.*
Polygonum convolvulus L. *248.*
Polygonum scandens L. *611.*

CHENOPODIACEAE

Cycloloma atriplicifolium (Spreng.) Coult. *3841.*
Chenopodium ambrosioides L. *812, 1043, 1549.*
Chenopodium anthelminticum L. *2923, 3442, 3846.*
Chenopodium hybridum L. *811, 3804, 3837.*
Chenopodium album L. *1040, 2041, 2357, 3838.*
Chenopodium Berlandieri Moq. *1042.*
Chenopodium murale L. *3106, 3419.*
Chenopodium Boscianum Moq. *787.*
Chenopodium leptophyllum Nutt. *1041.*
Chenopodium leptophyllum, var. oblongifolium S. Wats. *349.*

AMARANTHACEAE

Amaranthus retroflexus L. *427, 2624, 3114.*
Amaranthus hybridus L. *2827.*
Amaranthus graecizans L. *1038.*
Amaranthus blitoides S. Wats. *615.*
Amaranthus spinosus L. *345.*
Acnida tamariscina (Nutt.) Wood. *425, 1302, 1560.*
Iresine paniculata (L.) Ktze. *783, 1145, 1483.*

FROELICHIA GRACILIS Moq. *3227.*
SALSOLA KALI L.

PHYTOLACCACEAE

PHYTOLACCA DECANDRA L. *357.*

NYCTAGINACEAE

OXYBAPHUS NYCTAGINEUS (Michx.) Sweet. *436, 484, 3415.*
OXYBAPHUS FLORIBUNDUS Chois. *871, 1487, 3079.*
OXYBAPHUS ALBIDUS (Walt.) Sweet. *1096, 2761, 3135, 3651, 3480.*

ILLECEBRACEAE

ANYCHIA POLYGONOIDES Raf. *748, 1316, 1559.*
ANYCHIA CANADENSIS (L.) BSP. *423, 938.*

AIZOACEAE

MOLLUGO VERTICILLATA L. *341, 3886.*
GEOCARPON MINIMUM Mack. *3921, 5517.*

This interesting plant has so far been found only in one spot, in sandstone barrens on the high prairies, four miles north of Alba. In connection with his description of it[1] Mr. Kenneth K. Mackenzie says:

"This plant is probably to be referred to the family Aizoaceae, or as treated in the Synoptical Flora 1:256 the Ficoideae, and to the tribe Aizoideae of that family. In many respects it seems to come closer to the genus *Cypselea* than to any other North American genus. It differs markedly in the absence of stipules and style and in the capsule not being circumscissile. The other genera of the tribe in question, found in this country, are succulent plants with circumscissile capsules and cornute calyx-lobes.

"The tribe Mollugineae of the same family characterized by a calyx divided nearly or quite to the base, and represented in the United States by two genera having 3-celled ovaries, is less closely related to our plant. Nor can our plant be considered an apetalous representative of the Alsinaceae, as the sepals in that family are distinct or very nearly so. It seems in fact to represent a well-characterized genus."

[1]Torreya 14:67. 1914.

CARYOPHYLLACEAE

Spergula arvensis L. *3711.*
Sagina decumbens (Ell.) T. & G. *912.*
Arenaria serpyllifolia L. *1105.*
Arenaria patula Michx. *506, 1245.*
Stellaria media (L.) Cyrill. *504, 1752.*
Cerastium vulgatum L. *562, 3634.*
Cerastium viscosum L. *3272.*
Cerastium brachypodum (Engelm.) Robinson. *302, 568.*
Cerastium nutans Raf. *570, 1680, 3356.*
Agrostemma Githago L. *517, 2093.*
Silene antirrhina L. *413, 749, 889.*
Silene regia Sims. *278, 656.*
Silene stellata (L.) Ait. f. *342.*
Silene noctiflora L. *3974.*
Saponaria officinalis L. *435.*

PORTULACACEAE

Claytonia virginica L. *365.*

A form of this plant growing in low rich woods has leaves much broader than in the prairie plants, sometimes 1.5 cm. broad.

Talinum parviflorum Nutt. *2268.*
Talinum calycinum Engelm. *909, 2269.*
Portulaca oleracea L. *820.*
Portulaca neglecta Mack. & Bush. *3108.*
Portulaca pilosa L. *908, 1412.*

CERATOPHYLLACEAE

Ceratophyllum demersum L. *1438, 1815.*

NYMPHAEACEAE

Nymphaea advena Ait. *888, 1917.*

RANUNCULACEAE

Ranunculus aquatalis, var. capillaceus DC. *2028, 2313, 2320, 3783.*
Ranunculus oblongifolius Ell. *1961, 1965, 2037, 3055.*
Ranunculus micranthus Nutt. *571, 1661, 1665.*
Ranunculus abortivus L. *543, 752, 3650.*

RANUNCULUS RECURVATUS Poir. *911, 1893, 3777.*
RANUNCULUS FASCICULARIS Muhl. *145, 1607.*
RANUNCULUS SEPTENTRIONALIS Poir. *913, 1634.*
RANUNCULUS HISPIDUS Michx. *912, 1894.*
MYOSURUS MINIMUS L. *1630, 1660, 3390.*
THALICTRUM DASYCARPUM Fisch. & Lall. *2030.*
THALICTRUM REVOLUTUM DC. *496, 2110.*
ANEMONELLA THALICTROIDES (L.) Spach. *143, 144.*
ANEMONE CAROLINIANA Walt. *141, 142, 1765.*
ANEMONE VIRGINIANA L. *491, 915.*
CLEMATIS PITCHERI T. & G. *697, 698, 1101, 2326.*
CLEMATIS MISSOURIENSIS Rydb. *3690.*
ISOPYRUM BITERNATUM (Raf.) T. & G. *1618, 1761.*
AQUILEGIA COCCINEA Small. *587.*
DELPHINIUM TRICORNE Michx. *147.*
DELPHINIUM PENARDI Huth. *146, 1864.*
CIMICIFUGA RACEMOSA (L.) Nutt. *869, 1102, 2325.*

ANONACEAE

ASIMINA TRILOBA Dunal. *31, 37, 813.*

MENISPERMACEAE

COCCULUS CAROLINUS (L.) DC. *614, 894, 2377, 3429.*
MENISPERMUM CANADENSE L. *143, 2054.*
CALYCOCARPUM LYONI (Pursh) Nutt. *735, 3236.*

BERBERIDACEAE

PODOPHYLLUM PELTATUM L. *692, 3601.*
CAULOPHYLLUM THALICTROIDES (L.) Michx. *3944.*

LAURACEAE

SASSAFRAS VARIIFOLIUM (Salisb.) Ktze. *8, 34, 709, 710.*
BENZOIN AESTIVALE (L.) Nees. *20, 35, 383, 344, 708.*

PAPAVERACEAE

SANGUINARIA DILLENIANA Greene. *1107, 1137, 1610.*

FUMARIACEAE

DICENTRA CUCULLARIA (L.) Bernh. *290, 1635.*
CORYDALIS FLAVULA (Raf.) DC. *289, 1616, 1676.*
CORYDALIS CRYSTALLINA Engelm. *288, 888, 3412.*

Corydalis aurea Willd. *1625, 1678, 1702.*
Corydalis montana Engelm. *1645, 1674.*

CRUCIFERAE

Draba caroliniana Walt. *282, 1600, 1608.*
Draba cuneifolia Nutt. *1615, 1673.*
Draba brachycarpa Nutt. *285, 1609.*
Lepidium virginicum L. *943.*
Lepidium apetalum Willd. *287, 2161.*
Capsella Bursa-pastoris (L.) Medic. *283, 286, 1286, 3645.*
Camelina microcarpa Andrz. *2042.*
Brassica alba (L.) Boiss. *2553.*
Brassica arvensis (L.) Ktze. *540, 2458.*
Brassica japonica Siebold. *2346.*
Brassica nigra (L.) Koch. *2131.*
Brassica campestris L. (*6049* of *B. F. Bush*).
Sisymbrium officinale (L.) Scop. *459.*
Radicula Nasturtium-aquaticum (L.) Britten & Rendle. *940, 3282.*
Radicula sessiliflora (Nutt.) Greene. *1911, 1980, 3250, 3301.*
Radicula palustris (L.) Moench. *525, 3009.*
Radicula aquatica (Eat.) Robinson. *1285, 2184, 2486.*
Barbarea vulgaris R. Br. *1863.*
Selenia aurea Nutt. *942, 1603, 1799.*
Iodanthus pinnatifidus (Michx.) Steud. *405.*
Dentaria laciniata Muhl. *284, 682, 1284, 1662, 3337.*
Cardamine bulbosa (Schreb.) BSP. *1705, 1895.*
Cardamine rotundifolia Michx. *844.*

What appears to be this species has been found in a spring, near Spring River, four miles east of Carthage.

Cardamine parviflora L. *755, 3629.*
Cardamine arenicola Britton. *508, 1709, 1824, 3672.*
Cardamine pennsylvanica Muhl. *3615, 3657.*
Arabis dentata T. & G. *573, 1749.*
Arabis virginica (L.) Trel. *336, 757, 1283, 1599.*
Arabis hirsuta (L.) Scop. *941, 2535, 2960, 3701.*
Arabis laevigata (Muhl.) Poir. *486, 761.*
Arabis canadensis L. *497, 842, 3689.*

Sophia intermedia Rydb. *1149, 1629, 1640, 1732, 1804, 843, 841.*
Sophia pinnata (Walt.) Britton. *1147, 1703, 1739, 3660.*

CAPPARIDACEAE

Polanisia graveolens Raf. *2773.*
Cleome spinosa L. *870.*

CRASSULACEAE

Penthorum sedoides L. *610, 784, 2721.*
Sedum Nuttallianum Raf. *872.*
Sedum pulchellum Michx. *350.*
Sedum Nevii Gray. *3199, 3705.*

SAXIFRAGACEAE

Heuchera hirsuticaulis (Wheelock) Rydb. *530, 1108, 2536, 3654.*
Ribes missouriensis Nutt. *373, 575, 2009, 3596, 2373.*

PLATANACEAE

Platanus occidentalis L. *23, 1841.*

ROSACEAE

Opulaster intermedius Rydb. *6, 10, 1455.*
Gillenia stipulata (Muhl.) Trel. *351, 1091, 1132, 3754.*
Pyrus ioensis (Wood) Bailey. *105, 391, 1554, 3348, 3476, 3595.*
Pyrus ioensis, var. Palmeri Rehder. *2605, 3347, 3473.*
Pyrus Malus L. *467, 1722.*
Amelanchier canadensis (L.) Medic. *2, 27, 955, 1603, 3658, 1269, 1555.*
Crataegus strongylophylla Sarg. *1968, 1973, 1983, 2752, 2759, 2786.*
Crataegus tantula Sarg.
Crataegus ferox Sarg. *905, 916, 1579, 1580, 1581, 1582, 1583, 1584, 1585, 1586, 1587, 1588, 1870, 1984.*
Crataegus Palmeri Sarg. *1564, 1565, 1566, 1567, 1568, 1569, 1570, 1571, 1572, 1573, 1574, 1575, 1576, 1577, 3617.*
Crataegus rotunda Sarg. *1294, 1295, 1296, 1297, 1298, 1299, 1300, 1472, 1979.*
Crataegus parciflora Sarg. *1292, 1293.*
Crataegus jasperensis Sarg. *1290, 1291, 1578, 1579, 2758, 2869, 2881, 1886.*

Crataegus rubrisepala Sarg. *1284, 1285, 1301, 2700.*

Crataegus munita Sarg. *1468, 2006, 2728.*

Crataegus paradoxa Sarg. *1899, 1977, 1930, 1933, 1978, 2762, 2763, 2770, 2771, 2772.*

Crataegus rubrifolia Sarg. *1286, 1287, 1288, 1289, 1301, 1464, 1887, 1971, 2868.*

Crataegus vicina Sarg. *1232, 1263, 1265, 1266, 1230, 1231, 1264, 1463, 1786, 2886, 2887, 2888, 2889, 2890.*

Crataegus macropoda Sarg. *1227, 1228, 1229, 1257, 1258, 1259, 1260, 1261, 1262, 1263, 2736.*

Crataegus secta Sarg. *1225, 1226, 1255, 1256, 1467, 1728, 1731, 2656, 2658, 2838.*

Crataegus furcata Sarg. *1233, 1234, 1267, 1268, 1270, 1271, 1272, 1832, 1869, 2884.*

Crataegus lutensis Sarg. *2883.*

Crataegus ovata Sarg. *1959.*

Crataegus bracteata Sarg. *1253, 1254, 1274, 1828, 1842, 1885, 1876, 1469, 1474, 2603, 2755.*

Crataegus aspera Sarg. *1245, 1246, 1839, 2755, 2757.*

Crataegus disjuncta Sarg.

Crataegus magnifolia Sarg. *1247, 1248, 1249, 1250, 1251, 1252, 1469, 1831, 1648, 1867, 1872, 1890, 2799, 2800.*

Crataegus lasiantha Sarg. *1242, 1273, 1283, 1473, 1744, 2671, 2772, 2794, 2707, 1757.*

Crataegus dumetosa Sarg. *1462, 1470, 1692.*

Crataegus mollis (T. & G.) Scheele. *1282, 1700, 1746, 1748, 2715.*

Crataegus lanuginosa Sarg. *1235, 1237, 1238, 1239, 1240, 1241, 1243, 1273, 1811, 1814, 1843, 1782, 3618.*

Crataegus dasyphylla Sarg. *1712, 1768.*

Crataegus speciosa Sarg. *1219, 1220, 1221, 1222, 1223, 1224, 1243, 1244, 1777, 1780, 1801, 1807, 2650, 2738, 2740, 2858, 2862, 2873, 2874, 2875, 2876, 2973.*

Crataegus hispidula Sarg. *1276, 1277, 1465, 1471, 2032, 2084, 2744, 2073, 2709.*

Crataegus obscura Sarg. *1271, 1278, 1279, 2031, 2052, 2069, 2072, 2619, 2632, 2711, 3858.*

CRATAEGUS SPINULOSA Sarg. *1280, 1281, 2020, 2035, 2691, 2705, 2748, 3496.*

CRATAEGUS INSPERATA Sarg. *1274, 1275, 1466, 2039, 2063, 2064, 2777, 2863.*

CRATAEGUS MOLLICULA Sarg. *2036, 2037, 2055, 2749.*

CRATAEGUS SIMULATA Sarg. *1999, 2000, 2001, 2019, 2034, 2690, 2743, 2745.*

CRATAEGUS SPATHULATA, var. FLAVANTHA Sarg. *1994, 2856, 2870, 2871.*

Only one tree of this species has been found in a thicket near Joplin. This is the most northerly station recorded for this southern red haw, which is very common in some of the gulf states.

FRAGARIA VIRGINIANA Duch. *308.*

FRAGARIA VIRGINIANA, var. ILLINOENSIS (Prince) Gray. *1272.*

POTENTILLA MONSPELIENSIS L. *736, 803, 1985, 2113, 2411, 3758.*

POTENTILLA CANADENSIS L. *307, 907, 2479.*

A slender form found in the northwestern part of the county, with long filiform runners and under surface of leaves somewhat silvery, may be distinct.

GEUM CANADENSE Jacq. *497, 2190, 2414.*

GEUM VERNUM (Raf.) T. & G. *352, 544, 3368.*

RUBUS OCCIDENTALIS L. *740, 3454, 3497.*

RUBUS ALLEGHENIENSIS Porter. *1270.*

RUBUS ANDREWSIANUS Blanchard. *99, 2075, 3432, 3453.*

RUBUS PROCUMBENS Muhl. *305, 475, 1271, 2229, 2234, 3422, 3435.*

RUBUS RUBRISETUS Rydb. *1594.*

AGRIMONIA STRIATA Michx. *3126.*

AGRIMONIA MOLLIS (T. & G.) Britton. *306.*

AGRIMONIA PARVIFLORA Ait. *609, 1323.*

ROSA SETIGERA Michx. *33, 819, 2221, 2290.*

ROSA HELIOPHILA Greene. *50, 961, 2057, 2066, 2077, 2098, 2105, 2137, 2228.*

ROSA WOODSII Lindl. *2051, 2132, 2840, 3406, 3438, 3440.*

ROSA RUBIGINOSA L. *3187.*

ROSA HUMILIS Marsh. *98, 1274, 3775.*

ROSA RUDIUSCULA Greene. *3715, 3749.*

PRUNUS SEROTINA Ehrh. *12, 954, 3377.*

Prunus angustifolia Marsh. *2824, 3309.*

Prunus Munsoniana Wight. & Hedrick. *3100, 3310, 3318, 3334, 3023, 3098.*

Prunus Mahaleb L. *3149, 3378.*

Prunus Palmeri Sarg. *1677, 2233, 3525, 3904.*

Prunus hortulana Bailey. *44, 821, 822, 823, 958, 825, 3328, 3340, 3586.*

Prunus hortulana, var. pubens Sarg. *2164, 2893, 2897, 3045, 3073, 2901.*

Prunus Persica (L.) Stokes. *2419.*

Prunus lanata (Sudw.) Mack. & Bush. *45.*

To this species are doubtfully referred plums of the Americana group, common on prairies and in thickets and open woods. It is usually a shrub suckering freely and forming small thickets, producing small red acid fruit with a glaucous bloom. Occasionally it becomes a tree of considerable size. The true position of the species is still unsettled.

LEGUMINOSAE

Desmanthus illinoensis (Michx.) MacM. *431.*

Schrankia uncinata Willd. *531, 3457.*

Gymnocladus dioica (L.) Koch. *3, 3755.*

Gleditsia triacanthos L. *59, 729, 1541, 2186.*

Cassia Medsgeri Shafer. *126, 3441.*

Cassia Chamaecrista L. *124, 2643.*

Cassia nictitans L. *123, 3164, 3471.*

Cercis canadensis L. *49, 387.*

Baptisia bracteata (Muhl.) Ell. *128.*

Baptisia leucantha T. & G. *568, 2464.*

Baptisia australis (L.) R. Br. *127.*

Crotalaria sagittalis L. *440, 840.*

Trifolium arvense L. *3785.*

Trifolium pratense L. *686.*

Trifolium reflexum L. *500, 551, 1967, 3968.*

Trifolium stoloniferum Muhl. *3967.*

Trifolium repens L. *1064.*

Trifolium hybridum L. *1067, 2058.*

Trifolium carolinianum Michx. *1789, 2058.*

Trifolium procumbens L. *1065, 3040.*
Melilotus officinalis (L.) Lam.
Melilotus alba Desr. *492, 2230.*
Medicago sativa L. *2304.*
Hosackia americana (Nutt.) Piper. *595, 2597, 2968, 3877.*
Psoralea pedunculata (Mill.) Vail. *138.*
Psoralea tenuiflora Pursh. *139, 3367.*
Amorpha canescens Pursh. *20, 77.*
Amorpha fruticosa L. *15, 830.*
Petalostemum purpureum (Vent.) Rydb. *2983, 3487.*
Petalostemum purpureum, var. pubescens Gray. *202.*
Petalostemum candidum Michx. *201, 1066, 3466.*
Tephrosia virginiana (L.) Pers. *147, 2308, 3125.*
Robinia Pseudo-Acacia L. *886.*
Astragalus caryocarpus Ker. *399, 1290.*
Astragalus mexicanus A. DC. *3332.*
Astragalus canadensis L. *885.*
Astragalus distortus T. & G. *588, 1704, 1798, 1829, 1932, 1956.*
Desmodium nudiflorum (L.) DC. *2350, 2542, 2594.*
Desmodium grandiflorum (Walt.) DC. *129, 367, 2898.*
Desmodium pauciflorum (Nutt.) DC. *2585, 2595.*
Desmodium rotundifolium (Michx.) DC. *3059, 3121, 3160.*
Desmodium canescens (L.) DC. *419, 1067, 1068, 2539, 2589, 2615, 2697, 2687, 2696.*
Desmodium bracteosum (Michx.) DC. *2695, 3204.*
Desmodium illinoense Gray. *463, 2280.*
Desmodium Dillenii Darl. *765, 2676, 2678, 2694, 2751.*
Desmodium paniculatum, var. pubens T. & G. *2641, 2680, 2704.*
Desmodium canadense (L.) DC. *2572.*
Desmodium sessilifolium (Torr.) T. & G. *2582, 2681, 2760.*
Desmodium marilandicum (L.) DC. *891, 2679, 2774.*
Lespedeza repens (L.) Bart. *887.*
Lespedeza violacea (L.) Pers. *7, 135, 3205, 3469.*
Lespedeza prairea (Mack. & Bush) Britton. *890, 3848.*
Lespedeza Stuvei Nutt. *1062, 1063, 2826, 3468.*
Lespedeza virginica (L.) Britton. *133, 134, 771, 889, 3867.*
Lespedeza hirta (L.) Hornem. *888.*
Lespedeza capitata Michx. *3464, 3847.*

Lespedeza capitata, var. sericea H. & A. *140, 3458.*
Lespedeza striata (Thunb.) H. & A. *600.*
Stylosanthes biflora (L.) BSP. *131, 132, 461, 2253.*
Vicia villosa Roth. *2281.*
Lathyrus pusillus Ell. *2004.*
Apios tuberosa Moench. *3022.*
Phaseolus polystachyus (L.) BSP. *3218.*
Strophostyles helvola (L.) Britton. *778, 3876.*
Strophostyles umbellata (Muhl.) Britton. *892.*
Strophostyles pauciflora (Benth.) Wats. *817, 2522, 3070.*
Amphicarpa monoica (L.) Ell. *773.*
Amphicarpa Pitcheri T. & G. *3051, 3194.*
Galactia volubilis (L.) Britton. *436.*
Galactia volubilis, var. mississippiensis Vail. *2833.*

LINACEAE

Linum usitatissimum L. *899, 2543.*
Linum sulcatum Riddell. *264*
Linum medium (Planch.) Britton. *898, 1534, 2220, 2261.*

OXALIDACEAE

Oxalis violacea L. *259.*
Oxalis stricta L. *1106, 2049.*
Oxalis corniculata L. *260, 2965.*
Oxalis repens Thunb. *681, 1558.*
Oxalis interior Small. *433, 792, 877, 2556.*

GERANIACEAE

Geranium maculatum L. *680, 756.*
Geranium carolinianum L. *268, 2088.*

RUTACEAE

Zanthoxylum americanum Mill. *64, 392, 718, 3529.*
Ptelea trifoliata L. *24, 389, 707, 1516, 2263, 3801.*

SIMARUBACEAE

Ailanthus glandulosa Desf.

POLYGALACEAE

Polygala incarnata L. *187, 2294, 2435.*
Polygala sanguinea L. *188, 358, 2138, 2218, 2277.*
Polygala verticillata L. *823, 2367, 3763.*

EUPHORBIACEAE

Croton glandulosus L. *451, 1539.*
Croton capitatus Michx. *169, 170.*
Croton monanthogynus Michx. *166, 167.*
Crotonopsis linearis Michx. *612, 927, 1317, 3240.*
Acalypha virginica L. *791.*
Acalypha gracilens Gray. *364, 438.*
Tragia nepetaefolia Cav. *1111, 2986, 453.*
Tragia ramosa Torr. *160.*

This species of the stinging spurge appears to be quite distinct from *T. nepetaefolia* in the floral characters and in the stiff erect habit of growth. The latter is usually a more or less twining vine, sometimes 5 m. high or more.

Phyllanthus caroliniensis Walt. *449, 1281, 3283.*
Euphorbia Preslii Guss. *163, 397, 448, 813, 2719.*
Euphorbia maculata L. *450, 452, 926, 2718.*
Euphorbia marginata Pursh. *3072, 3127.*
Euphorbia corollata L. *158, 164, 165.*
Euphorbia dentata Michx. *168, 834, 2374.*
Euphorbia heterophylla L. *161, 162, 3123, 3219.*
Euphorbia missouriensis (Norton) Small. *1922, 2139.*

CALLITRICHACEAE

Callitriche heterophylla Pursh. *886, 1614, 1658, 1816, 3731.*
Callitriche deflexa, var. Austini (Engelm.) Hegelm. *1905, 3015, 3728, 3681.*

ANACARDIACEAE

Rhus glabra L. *75, 1128.*
Rhus copallina L. *15, 959.*
Rhus Toxicodendron L. *52, 1517, 1903, 2135.*
Rhus canadensis Marsh. *7, 1866.*
Rhus trilobata Nutt. *706, 873, 1109, 1900, 1805.*

This shrub, commonly known as polecat bush, is quite distinct from *Rhus canadensis*. It is usually found on dry limestone ledges or rocky bluffs and is a stout shrub 1 to 1.5 m. high, with stems sometimes 4 or 5 cm. in diameter. It flowers much later than *R. canadensis*, the leaves being more than half grown at the time of blooming. *R. canadensis*, a slender shrub, is one of the earliest flowering plants of spring.

AQUIFOLIACEAE

Ilex decidua Walt. *1309, 1310, 1326, 1822.*

CELASTRACEAE

Evonymus atropurpureus Jacq. *46, 1518.*
Celastrus scandens L. *77, 712.*

STAPHYLEACEAE

Staphylea trifolia L. *66, 817, 818, 3531.*

ACERACEAE

Acer saccharum Marsh. *31, 384, 3671, 3532.*
Acer saccharinum L. *21, 377, 381.*
Negundo aceroides Moench. *11, 382, 923, 1686, 3519.*

The box elders differ much in foliage and to some extent in the fruit. There are two rather distinct forms in our region: one with glabrous twigs and leaves is the true *Acer Negundo* or *Negundo Negundo,* to adopt the more recent name; the form with broad rugose pubescent leaflets is *N. texanum* of Rydberg. The fruit in both these species is somewhat constricted into a stipe-like base. A third form with pubescent leaves and fruit not so constricted has been distinguished as *N. interius* Rydberg.

SAPINDACEAE

Sapindus Drummondi H. & A. *3984, 4020.*

The most northerly station recorded for this tree, popularly called soapberry or wild chinaberry, is along a small creek near Careytown, in the northern part of our county. It has been found at two other stations in the county, both of them on Center Creek. It grows along dry limestone bluffs having a southern exposure. There are not many plants at either of these colonies and it is not unlikely that it may become extinct in our area.

Aesculus glabra Willd. *1681, 1685, 1758, 3530.*

BALSAMINACEAE

Impatiens pallida Nutt. *361.*
Impatiens biflora Walt. *467.*

RHAMNACEAE

Rhamnus lanceolata Pursh. *56, 70.*

CEANOTHUS AMERICANUS L. *40, 813.*
CEANOTHUS OVATUS, var. PUBESCENS T. & G. *395, 2258.*

VITACEAE

PSEDERA QUINQUEFOLIA (L.) Greene. *1265, 3842.*
PSEDERA QUINQUEFOLIA, var. HIRSUTA (Donn) Rehder. *1264.*
PSEDERA QUINQUEFOLIA, var. SAINT-PAULII (Koehne & Grabner) Rehder. *80, 1496.*
CISSUS AMPELOPSIS Pers. *67, 1589, 4002.*
VITIS CINEREA Engelm. *458, 2045, 2185, 2249, 2499.*
VITIS BICOLOR Le Conte. *2822.*
VITIS CORDIFOLIA Michx. *53, 67, 897, 3966.*
VITIS LINSECOMII Buckley. *58, 1318, 2104, 2461, 2462, 2661, 3992.*
VITIS LINSECOMII, var. GLAUCA Munson. *2209, 2244, 2245, 2475, 4028.*

MALVACEAE

ABUTILON THEOPHRASTI Medic. *915, 2561.*
MALVASTRUM ANGUSTUM Gray. *437, 1547.*
SIDA SPINOSA L. *596, 2470.*
MALVA ROTUNDIFOLIA L. *882.*
CALLIRHOE DIGITATA Nutt. *348, 3420.*
HIBISCUS SYRIACUS L. *3460.*
HIBISCUS INCANUS Wendland. *1089, 1306, 1548.*
HIBISCUS MILITARIS Cav. *802, 1305.*
HIBISCUS TRIONUM L. *839, 2600, 3450.*

HYPERICACEAE

ASCYRUM HYPERICOIDES L. *538, 1670.*
HYPERICUM PUNCTATUM Lam. *2383, 2412.*
HYPERICUM PSEUDOMACULATUM Bush. *2971.*
HYPERICUM PROLIFICUM L. *1263, 1902, 3012.*
HYPERICUM CISTIFOLIUM Lam. *174, 175, 896.*
HYPERICUM MUTILUM L. *177, 1097.*
HYPERICUM DRUMMONDII (Grev. & Hook.) T. & G. *262, 880, 1103, 3226, 3241.*

CISTACEAE

HELIANTHEMUM MAJUS BSP. *523.*

Lechea villosa Ell. *796, 900, 1315.*
Lechea tenuifolia Michx. *266, 836.*

VIOLACEAE

Hybanthus concolor (Forster) Spreng. *884, 1683, 1835, 3172.*
Viola pedata, var. linariloba DC.
Viola missouriensis Greene. *1663, 1675, 1707, 1905, 2022, 3404, 3738.*
Viola papilionacea Pursh. *1639, 1686, 1957, 3267.*
Viola palmata, var. dilatata Ell. *1951.*
Viola triloba Schwein. *1665, 1715, 3041, 3333, 3351, 3666, 3688, 3552, 3703.*
Viola sororia Willd. *845, 1110, 272, 1626, 1633, 1716, 846, 847, 1687, 2089, 3335.*
Viola fimbriatula Sm. *3343, 3376.*
Viola sagittata Ait. *1638, 1897, 3391, 3399, 3588, 3605, 3717.*
Viola emarginata Le Conte. *760, 1766, 3066, 3587, 3717.*
Viola pedatifida G. Don. *561, 1644, 1764, 3346.*
Viola scabriuscula Schwein. *271, 574, 1706, 1713, 1714, 737.*
Viola viarum Pollard. *1687.*
Viola Rafinesquii Greene. *673, 674, 1929.*
Viola papilionacea × triloba. *2256, 3357, 3360, 3603, 3665.*
Viola papilionacea × pedatifida. *3331, 3345, 3393, 3425, 3593, 3912.*
Viola sororia × triloba. *565.*
Viola emarginata × sororia. *1260, 3395.*

PASSIFLORACEAE

Passiflora lutea L. *141, 879, 2427.*
Passiflora incarnata L. *6371.*

LOASACEAE

Mentzelia oligosperma Nutt. *1099, 2356, 3004.*

CACTACEAE

Opuntia humifusa Raf. *2142.*
Opuntia macrorhiza ? Engelm. *2278.*

LYTHRACEAE

Didiplis diandra (Nutt.) Wood. *1254, 3844.*
Rotala ramosior (L.) Koehne. *800, 1476, 2419, 2626, 3246, 3821.*

AMMANNIA COCCINEA Rottb. *2575, 4007.*
AMMANNIA AURICULATA Willd. *1104, 3248, 3822.*
LYTHRUM ALATUM Pursh. *267, 2337.*
CUPHEA PETIOLATA (L.) Koehne. *279, 2337.*

MELASTOMACEAE

RHEXIA LATIFOLIA Bush. *923, 949, 1256, 1907, 2433, 3049.*

ONAGRACEAE

JUSSIAEA DIFFUSA Forsk. *910, 914, 2639.*
LUDVIGIA ALTERNIFOLIA L. *176, 801, 1243.*
LUDVIGIA PALUSTRIS (L.) Ell. *1297, 2429, 3273, 3281, 3806.*
OENOTHERA MURICATA L. *416, 780.*
OENOTHERA MURICATA, var. CANESCENS (T. & G.) Robinson. *2571.*
OENOTHERA BIENNIS L. *807.*
OENOTHERA LACINIATA Hill. *301, 3649, 3746.*
OENOTHERA LACINIATA, var. GRANDIFLORA (Wats.) Robinson. *550.*
OENOTHERA SPECIOSA Nutt. *480, 2083.*
OENOTHERA LINIFOLIA Nutt. *263, 2121, 3682.*
GAURA BIENNIS L. *112.*
GAURA PITCHERI (T. & G.) Small. *102, 2549, 2640, 2660, 3113, 3147.*
GAURA PARVIFLORA Dougl. *2494, 2591.*
CIRCAEA LUTETIANA L. *469, 881.*

HALORAGIDACEAE

MYRIOPHYLLUM SCABRATUM Michx. *3242.*
MYRIOPHYLLUM PROSERPINACOIDES Gill. *743, 3275.*
Established in a pond four miles northwest of Joplin.
PROSERPINACA PALUSTRIS L. *3257.*

UMBELLIFERAE

ERYNGIUM YUCCIFOLIUM Michx. *359, 1080.*
SANICULA GREGARIA Bicknell. *368.*
SANICULA CANADENSIS L. *2133, 2343.*
ERIGENIA BULBOSA (Michx.) Nutt. *684, 759, 1598.*
CHAEROPHYLLUM PROCUMBENS (L.) Crantz. *335, 572, 1619, 1812,* (*1559* of *B. F. Bush*).
CHAEROPHYLLUM TEXANUM Coult. & Rose. *494, 1081, 2331.*

Osmorhiza Claytoni (Michx.) Clarke. *1892.*
Osmorhiza longistylis (Torr.) DC. *683, 1262.*
Spermolepis patens (Nutt.) Robinson. *476, 530, 2310, 2345.*
Spermolepis echinata (Nutt.) Heller. *2361.*
Ptilimnium Nuttallii (DC.) Britton. *137, 2490.*
Cicuta maculata L. *172, 2491, 2557.*
Cryptotaenia canadensis (L.) DC. *490, 2134.*
Zizia aurea (L.) Koch. *511, 1719.*
Zizia cordata (Walt.) DC. *1988.*
Taenidia integerrima (L.) Drude. *171, 2087.*
Eulophus americanus Nutt. *489, 2210.*
Conium maculatum Michx. *3707, 3997.*
Thaspium barbinode (Michx.) Nutt. *533, 1808, 2417.*
Polytaenia Nuttallii DC. *583, 685.*
Pastinaca sativa L. *2092.*
Heracleum lanatum Michx. *1825, 2029.*
Torilis Anthriscus (L.) Bernh. *2221, 2384, 3977.*
Daucus Carota L. *2371, 3191.*
Daucus pusillus Michx. *539, 2270.*

CORNACEAE

Cornus florida L. *63, 89, 814, 815, 816, 3632.*
Cornus Amomum Mill. *60, 375.*
Cornus asperifolia Michx. *57, 817, 1307, 2975, 2201.*
Cornus Baileyi Coult. & Evans. *1308, 2418.*

ERICACEAE

Monotropa uniflora L. *3155, 3254.*

The curious and delicate Indian pipe or ghost plant has been found growing up through the humus in deep oak woods at several places in the county.

Monotropa Hypopitys L. *2352.*

This species, known as pine sap, appears to be a great rarity, only a few plants having been found, June 27, 1909, on gravelly banks, growing with "reindeer moss," near Scotland Spring.

Vaccinium arboreum Marsh.

The tree huckleberry and the next species, the low bush huckleberry, barely get into our county in the southwestern

part. They are both abundant in the rocky woods bordering Shoal Creek, a little farther south in Newton County.

Vaccinium tenellum Ait. *2501.*

PRIMULACEAE

Androsace occidentalis Pursh. *545, 696, 3584.*

Samolus floribundus HBK. *1251, 2243, 2537, 2781.*

Steironema ciliatum (L.) Raf. *30, 738, 1090.*

Steironema lanceolatum (Walt.) Gray. *3887.*

Dodecatheon Meadia L. *585, 919, 920, 1726, 2702.*

Centunculus minimus L. *3733.*

SAPOTACEAE

Bumelia lanuginosa (Michx.) Pers. *28, 927, 2655.*

EBENACEAE

Diospyros virginiana L. *62, 3974.*

There is much variation in the fruit and foliage of the persimmon. The common variety sometimes becomes a tree 10 or 12 m. high, forming small groves or thickets on upland prairies. The fruit is scarcely edible until after the first frosts. A not uncommon form, growing in similar situations, has large pubescent leaves with cordate bases which turn a bright yellow in autumn. Small trees producing very large soft pulpy fruit ripening early in September may belong to a distinct species.

OLEACEAE

Fraxinus americana L. *924, 1542, 3533, 3636, 3667.*

Fraxinus lanceolata Borkh. *12, 117, 1513, 1776.*

Fraxinus quadrangulata Michx. *1124, 1515, 2080.*

Adelia acuminata Michx. *1249, 1627, 2074, 2188.*

APOCYNACEAE

Amsonia salicifolia Pursh. *296. 2488.*

This species grows usually along gravelly branches, in large frutescent clumps 1 m. or more high. The leaves are narrower and the flowers smaller than in the next species, from which it appears quite distinct.

Amsonia Tabernaemontana Walt. *921, 1819.*

Apocynum cannabinum L. *208, 1093, 1094, 3188.*

Apocynum pubescens R. Br. *2336, 3426.*
Apocynum leuconeuron Greene. *3979, 4006.*
Apocynum androsaemifolium L. *2172.*

GENTIANACEAE

Sabatia angularis (L.) Pursh. *405, 2506.*
Sabatia campestris Nutt. *363, 569, 2512.*
Gentiana puberula Michx. *344, 691, 3269.*
Gentiana Andrewsii Griseb. *1410, 1519, 3235, 3884.*
Gentiana flavida Gray. *1592, 3128.*

ASCLEPIADACEAE

Asclepiodora viridis (Walt.) Gray. *207.*
Asclepias tuberosa L. *211, 2820.*
Asclepias purpurascens L. *213, 2235.*
Asclepias incarnata L. *2, 1536.*
Asclepias kansana Vail. *929.*
Asclepias amplexicaulis J. E. Smith. *492, 946, 3035, 3734.*
Asclepias quadrifolia Jacq. *214, 3695.*
Asclepias verticillata L. *210, 819.*
Asclepias stenophylla Gray. *2309.*
Acerates floridana (Lam.) Hitchc. *209, 911.*
Acerates viridiflora Ell. *1113.*
Acerates viridiflora, var. Ivesii Britton. *212.*
Gonolobus laevis Michx. *824, 1794, 3810.*
Vincetoxicum carolinense (Jacq.) Britton. *206, 3956.*
Vincetoxicum Baldwinianum (Sweet) Britton. *2416.*

CONVOLVULACEAE

Ipomoea coccinea L. *402, 1293.*
Ipomoea hederacea Jacq. *822, 3855.*
Ipomoea purpurea (L.) Roth. *401, 821.*
Ipomoea pandurata (L.) Meyer. *415, 1295.*
Ipomoea lacunosa L. *768, 828, 2819.*
Convolvulus sepium L. *3075, 3136.*
Convolvulus repens L. *3428.*
Convolvulus fraterniflorus Mack. & Bush. *3451.*
Convolvulus arvensis L. *523, 529.*
Cuscuta obtusiflora HBK. *808, 1291, 1392, 3274.*
Cuscuta arvensis Beyrich. *432, 3063.*

CUSCUTA CEPHALANTHI Engelm. *3197, 3835.*
CUSCUTA GRONOVII Willd. *2737, 3821.*
CUSCUTA PARADOXA Raf. *818, 3069, 3129, 3861.*

POLEMONIACEAE

PHLOX PILOSA L. *503, 1546, 1742, 3957.*
PHLOX DIVARICATA L. *398, 557.*
POLEMONIUM REPTANS L. *581, 953, 1545.*

HYDROPHYLLACEAE

HYDROPHYLLUM VIRGINIANUM L. *319, 2040, 2076.*
ELLISIA NYCTELEA L. *738, 1853.*
PHACELIA DUBIA (L.) Small. *261, 1879, 1888.*
PHACELIA HIRSUTA Nutt. *739, 2048.*

BORAGINACEAE

HELIOTROPIUM TENELLUM (Nutt.) Torr. *439, 478, 1070, 2525, 3849.*
LAPPULA VIRGINIANA (L.) Greene. *422, 874, 2604, 3797.*
MYOSOTIS VIRGINICA (L.) BSP. *507, 547, 3621, 3637.*
MYOSOTIS VIRGINICA, var. MACROSPERMA (Engelm.) Fernald. *1906, 3569, 3663.*
LITHOSPERMUM CANESCENS (Michx.) Lehm. *579, 1612, 3622.*
LITHOSPERMUM ARVENSE L. *3406.*
LITHOSPERMUM ANGUSTIFOLIUM Michx. *580, 1590, 2370, 2381.*
ONOSMODIUM MOLLE Michx. *2050, 2140.*
ONOSMODIUM OCCIDENTALE Mack. *1069.*
ONOSMODIUM HISPIDISSIMUM Mack. *347, 472, 2303.*

VERBENACEAE

VERBENA URTICAEFOLIA L. *197.*
VERBENA ANGUSTIFOLIA Michx. *200, 2981, 3319.*
VERBENA HASTATA L. *189, 1085, 1086, 2483.*
VERBENA STRICTA Vent. *199, 675, 2980.*
VERBENA BRACTEOSA Michx. *454.*
VERBENA CANADENSIS (L.) Britton. *304, 559.*
VERBENA ANGUSTIFOLIA × STRICTA *2932.*
VERBENA BRACTEOSA × STRICTA *601, 4025.*
LIPPIA LANCEOLATA Michx. *362, 2996, 3111, 3247, 3820.*

LABIATAE

Teucrium canadense L. *277, 2541, 2568.*
Isanthus brachiatus (L.) BSP. *934, 950, 3087.*
Scutellaria lateriflora L. *932, 2651.*
Scutellaria incana Muhl. *8, 652.*
Scutellaria cordifolia Muhl. *931, 2351, 2355, 2372.*
Scutellaria parvula Michx. *505, 510, 516, 545, 2526.*
Marrubium vulgare L. *474.*
Agastache nepetoides (L.) Ktze. *772, 1058, 3095.*
Nepeta Cataria L. *276.*
Nepeta hederacea (L.) Trevisan. *1679, 2060, 3990.*
Prunella vulgaris L. *280.*
Physostegia virginiana (L.) Benth. *196.*
Lamium amplexicaule L. *1622, 1710.*
Lamium purpureum L. *1753, 1989.*
Leonurus Cardiaca L. *1060, 3782.*
Stachys tenuifolia Willd. *429, 598, 790, 3021.*
Stachys latidens Small. *2569.*
Salvia Pitcheri Torr. *118, 1061.*
Salvia lanceaefolia Poir. *1312, 3285.*
Monarda fistulosa L. *3060.*
Monarda mollis L. *203, 1059, 3043,* (*6045* of *B. F. Bush.*)
Monarda Bradburiana Beck. *518, 2318.*
Monarda citriodora Cerv. *3800.*
Blephilia ciliata (L.) Raf. *2952.*
Blephilia hirsuta (Pursh) Benth. *470, 3078.*
Hedeoma pulegioides (L.) Pers. *770.*
Hedeoma hispida Pursh. *515.*
Hedeoma acinoides Scheele. *2007.*
Melissa officinalis L. *935.*
Pycnanthemum flexuosum (Walt.) BSP. *320, 2782.*
Pycnanthemum pilosum Nutt. *317, 3809.*
Cunila origanoides (L.) Britton. *3200.*
Lycopus rubellus Moench. *933, 1311, 3883.*
Lycopus virginicus L. *3260.*
Lycopus membranaceus Bicknell. *3843.*
Lycopus americanus Muhl. *424, 3857.*
Mentha rotundifolia (L.) Huds. *1987, 3042.*

MENTHA SPICATA L. *1057, 2473, 2581.*
MENTHA PIPERITA L. *2024, 2331.*
MENTHA CITRATA Ehrh. *3185.*
MENTHA CANADENSIS, var. GLABRATA Benth. *2780, 3223.*
PERILLA FRUTESCENS (L.) Britton. *930.*

SOLANACEAE

SOLANUM NIGRUM L. *257, 3109, 3208, 3220, 3227.*
SOLANUM CAROLINENSE L. *256.*
SOLANUM ELAEAGNIFOLIUM Cav. *918, 1324.*
SOLANUM ROSTRATUM Dunal. *477.*
PHYSALIS ANGULATA L. *3093, 3221.*
PHYSALIS PUBESCENS L. *805.*
PHYSALIS PRUINOSA L. *2552, 3198.*
PHYSALIS BARBADENSIS Jacq. *2466.*
PHYSALIS MISSOURIENSIS Mack. & Bush. *1252, 2988.*
PHYSALIS PUMILA Nutt. *253, 779, 1136, 2510, 2530.*
PHYSALIS HETEROPHYLLA Nees. *526, 917, 2081, 2511.*
PHYSALIS SUBGLABRATA Mack. & Bush. *255, 414, 904, 3110.*
PHYSALIS VIRGINIANA Mill. *254, 2008, 2500, 3776.*
LYCIUM HALIMIFOLIUM Mill. *1135.*
DATURA STRAMONIUM L. *2487.*
DATURA TATULA L. *258.*
DATURA METEL L. *916.*

SCROPHULARIACEAE

VERBASCUM THAPSUS L. *679.*
VERBASCUM BLATTARIA L. *269, 270, 4021.*
LINARIA VULGARIS Hill. *3044.*
LINARIA CANADENSIS (L.) Dumont. *896, 897, 1785.*
COLLINSIA VIOLACEA Nutt. *281, 947, 1767, 1823, 1856.*
SCROPHULARIA MARILANDICA L. *434, 1296.*
PENTSTEMON TUBIFLORUS Nutt. *90, 195.*
PENTSTEMON DIGITALIS (Sweet) Nutt. *194, 483, 937.*
MIMULUS RINGENS L. *1481.*
MIMULUS ALATUS Ait. *420, 951, 1075, 1550.*
CONOBEA MULTIFIDA (Michx.) Benth. *430.*
BACOPA ACUMINATA (Walt.) Robinson. *799, 840, 2816.*
BACOPA ROTUNDIFOLIA (Michx.) Wettst. *338, 2383.*

Ilysanthes dubia (L.) Barnhart. *1299, 3249.*
Ilysanthes anagallidea (Michx.) Robinson. *360, 1053, 1492.*
Gratiola virginiana L. *512, 549, 1992, 2124, 3685.*
Gratiola sphaerocarpa Ell. *1966, 2176, 2297.*
Veronica virginica L. *11.*
Veronica peregrina L. *355, 3647, 3680.*
Veronica arvensis L. *363, 1806.*
Dasistoma macrophylla (Nutt.) Raf. *418.*
Aureolaria grandiflora, var. cinerea Pennell. *1, 10, 1298, 2616.*
Tomanthera auriculata (Michx.) Raf. *613, 825.*
Agalinis aspera (Doug.)Britton. *2674.*
Agalinis fasciculata (Ell.) Raf. *604, 938, 1054, 1477, 3816, 3817, 3833, 3863.*
Agalinis tenuifolia (Vahl) Raf. *939, 833, 1140, 3132, 3148, 3818, 3862, 3875.*
Agalinis Besseyana Britton. *603, 1055, 2645, 3232, 3871, 3884.*
Agalinis Gattingeri Small. *936, 1056, 1422, 2302, 3103, 3131, 3202, 3206.*
Agalinis viridis (Small) Pennell. *816.*
Buchnera americana L. *108, 2441, 3064.*
Castilleja coccinea (L.) Spreng. *502, 3408, 3639, 3640.*
Pedicularis canadensis L. *549.*

LENTIBULARIACEAE

Utricularia vulgaris L. *2321, 3259.*
Utricularia minor L. *3258.*

OROBANCHACEAE

Orobanche uniflora L. *703.*

BIGNONIACEAE

Tecoma radicans (L.) Juss. *18.*
Catalpa speciosa Warder. *884.*
Catalpa bignonioides Walt. *2307.*

ACANTHACEAE

Dianthera americana L. *297, 458.*
Ruellia ciliosa Pursh. *356, 1309.*
Ruellia strepens L. *528, 1310.*
Diapedium brachiatum (Pursh) Ktze. *599, 1482, 1591.*

PHRYMACEAE

PHRYMA LEPTOSTACHYA L. *455, 1098.*

PLANTAGINACEAE

PLANTAGO MAJOR L. *2580.*
PLANTAGO RUGELII Dene. *157, 2349.*
PLANTAGO LANCEOLATA L. *159.*
PLANTAGO MEDIA L. *1854.*
PLANTAGO ARISTATA Michx. *235.*
PLANTAGO VIRGINICA L. *158, 1244, 1889, 1975.*
PLANTAGO ELONGATA Pursh. *546, 1790.*

RUBIACEAE

GALIUM VIRGATUM Nutt. *542, 2143.*
GALIUM APARINE L. *2025.*
GALIUM VAILLANTII DC. *353.*
GALIUM PILOSUM Ait. *336, 746, 747, 2248.*
GALIUM CIRCAEZANS Michx. *354.*
GALIUM TINCTORIUM L. *2180, 2208, 3745.*
GALIUM CONCINNUM T. & G. *522, 1082, 2215, 3725.*
GALIUM TRIFLORUM Michx. *1076, 2252, 2375.*
SPERMACOCE GLABRA Michx. *411, 782.*
DIODIA TERES Walt. *265, 273, 1255, 1325.*
CEPHALANTHUS OCCIDENTALIS L. *29, 396.*
HOUSTONIA MINIMA Beck. *653, 654, 1133, 3543, 3619, 3643.*
HOUSTONIA PURPUREA L. *1250, 3011.*

CAPRIFOLIACEAE

LONICERA SEMPERVIRENS L. *3186.*
LONICERA DIOICA L. *1912, 2078.*
LONICERA JAPONICA Thunb. *465, 607, 1077.*
SYMPHORICARPOS ORBICULATUS Moench. *97, 733, 734, 737, 796.*
TRIOSTEUM PERFOLIATUM L. *731, 732.*
VIBURNUM LENTAGO L. *9, 1556.*
VIBURNUM PRUNIFOLIUM L. *30, 378, 898, 1144, 3610.*
VIBURNUM RUFIDULUM Raf. *69, 394, 734, 1253.*
SAMBUCUS CANADENSIS L. *76, 1439, 3798.*
SAMBUCUS CANADENSIS, var. SUBMOLLIS f. ENGELMANNI Rehder. *3445, 3779.*

VALERIANACEAE

Valerianella radiata (L.) Dufr. *303, 1248, 1993.*

CUCURBITACEAE

Sicyos angulatus L. *597, 781.*

Echinocystis lobata (Michx.) T. & G. *878, 1259.*

CAMPANULACEAE

Specularia perfoliata (L.) A. DC. *570, 671, 2148, 2158, 3962.*

Specularia biflora (R. & P.) Fisch. & Mey. *481.*

Specularia leptocarpa (Nutt.) Gray. *925, 2262, 2302, 3982.*

Campanula americana L. *341, 672.*

LOBELIACEAE

Lobelia cardinalis L. *803, 910, 1134.*

Lobelia siphilitica L. *602.*

Lobelia leptostachys A. DC. *190, 924.*

Lobelia spicata, var. hirtella Gray. *191, 457, 2095.*

Lobelia inflata L. *417, 466, 3802.*

COMPOSITAE

Cichorium Intybus L. *3046.*

Serinia oppositifolia (Raf.) Ktze. *366.*

Krigia occidentalis Nutt. *3936.*

Krigia virginica (L.) Willd. *1883, 3668.*

Krigia Dandelion (L.) Nutt. *332, 1858.*

Krigia amplexicaulis Nutt. *655, 1891.*

Taraxacum officinale Weber. *566, 3949.*

Sonchus arvensis L. *3239.*

Sonchus asper (L.) Hill. *316, 2968.*

Lactuca scariola L. *2463.*

Lactuca scariola, var. integrata Gren. & Godr. *413, 1083, 1084.*

Lactuca canadensis L. *904, 2698, 3130.*

Lactuca sagittifolia Ell. *412.*

Lactuca villosa Jacq. *794.*

Lactuca floridana (L.) Gaertn. *802.*

Prenanthes aspera Michx. *312, 3176.*

Pyrrhopappus carolinianus (Walt.) DC. *329, 541, 2194.*

Hieracium scabrum Michx. *3165.*

Hieracium Gronovii L. *498, 2257, 3082, 3124, 3166.*

Hieracium longipilum Torr. *462, 2998, 4018.*
Iva ciliata Willd. *785.*
Ambrosia bidentata Michx. *426.*
Ambrosia trifida L. *774, 1141.*
Ambrosia artemisiaefolia L. *428.*
Ambrosia psilostachya DC. *2559, 2663.*
Xanthium echinatum Murr. *1303.*
Xanthium pennsylvanicum Wallr. *766, 767.*
Xanthium commune Britton. *1039, 1300.*
Xanthium glabratum Britton. *1301, 1304.*
Vernonia crinita Raf. *103, 2576, 2684, 3243, 3244.*
Vernonia altissima Nutt. *789.*
Vernonia Baldwini Torr. *94, 2560, 2586, 2614, 2722, 2724, 2732.*
Vernonia Baldwini × crinita. *2654, 2724.*
Elephantopus carolinianus Willd. *349.*
Eupatorium maculatum L. *331, 4014.*
Eupatorium serotinum Michx. *2683.*
Eupatorium altissimum L. *17, 2642, 2685.*
Eupatorium perfoliatum L. *863.*
Eupatorium urticaefolium Reichard. *107, 3887.*
Eupatorium coelestinum L. *326, 913, 3105.*
Kuhnia eupatorioides L. *328, 1035, 2731.*
Liatris squarrosa Willd. *860, 861, 1351, 3856.*
Liatris scariosa Willd. *112, 2849.*
Liatris pycnostachya Michx. *1033, 1348.*
Grindelia lanceolata Nutt. *181, 2578.*
Amphiachyris dracunculoides (DC.) Nutt. *113, 4033.*
Chrysopsis pilosa Nutt. *1346, 3026.*
Solidago speciosa Nutt. *2823, 3872.*
Solidago rigidiuscula (T. & G.) Porter. *1012, 2677.*
Solidago arguta Ait. *2688.*
Solidago ulmifolia Muhl. *12, 916.*
Solidago rugosa Mill. *109, 110.*
Solidago glaberrima Martens. *1010, 2565, 3068, 3988.*
Solidago nemoralis Ait. *2693, 2839, 3853, 3868.*
Solidago radula Nutt. *2831.*
Solidago altissima L. *1006.*
Solidago altissima, var. procera (Ait.) Fernald. *1008, 1009.*

Solidago serotina Ait. *1007, 1350.*
Solidago rigida L. *111.*
Solidago petiolaris Ait. *88, 325.*
Solidago Wardii Britton. *1350, 2622, 2694, 3190, 3869.*
Euthamia graminifolia (L.) Nutt. *196.*
Boltonia asteroides (L.) L'Her. *209, 220, 3853.*
Boltonia latisquama Gray. *3873.*
Aster paludosus Ait. *605, 1328, 3177.*
Aster oblongifolius, var. rigidulus Gray. *907, 1336, 1337, 3852.*
Aster patens Ait. *1475, 3866, 1335.*
Aster anomalus Engelm. *1338, 1339.*
Aster azureus Lindl. *101, 914, 1331.*
Aster sagittifolius Wedemeyer. *87, 324, 1332.*
Aster Drummondii Lindl. *851, 3864.*
Aster turbinellus Lindl. *323, 1334, 3865.*
Aster ericoides L. *1329.*
Aster ericoides, var. pilosus Porter. *1327, 1595, 2778.*
Aster multiflorus Ait. *2814, 51, 1015, 1030.*
Aster Tradescanti L. *1015, 1326, 2846.*
Aster paniculatus Lam. *852.*
Aster salicifolius Ait. *83, 106, 1014, 3885.*
Aster linariifolius L. *865, 905.*
Erigeron pulchellus Michx. *564, 692, 824, 1341.*
Erigeron philadelphicus L. *698, 1340, 1831, 1972.*
Erigeron annuus (L.) Pers. *754, 3965, 3954.*
Erigeron ramosus (Walt.) BSP. *204, 1029, 2109, 3958, 3980.*
Erigeron tenuis T. & G. *1898, 2003.*
Erigeron nudiflorus T. & G. *2097.*
Pluchea petiolata Cass. *1511, 3880.*
Antennaria occidentalis Greene. *313.*
Antennaria longifolia Greene. *3901.*

There are probably two or three other species of this genus occurring in the county, the classification of which is not clear at present.

Gnaphalium purpureum L. *524, 1344, 3010.*
Gnaphalium obtusifolium L. *2725, 3201.*
Polymnia uvedalia L. *327, 866, 3159.*

Silphium laciniatum L. *183, 3439.*
Silphium integrifolium Michx. *857, 3459, 1024, 1345.*
Silphium perfoliatum L. *774, 3805.*
Berlandiera texana DC. *2316.*
Parthenium integrifolium L. *536, 952.*
Parthenium repens Eggert. *700, 701, 3961, 3978.*
Eclipta alba (L.) Hassk. *404, 3719.*
Rudbeckia triloba L. *1021, 3209, 3430.*
Rudbeckia subtomentosa Pursh. *867, 1022, 1347, 2415.*
Rudbeckia hirta L. *182, 1020, 2319, 3788.*
Rudbeckia speciosa Wenderoth. *3234.*
Rudbeckia laciniata L. *1036.*
Rudbeckia amplexicaulis Vahl. *2255.*
Brauneria pallida (Nutt.) Britton. *187.*
Lepachys pinnata (Vent.) T. & G. *1031, 1032, 2563.*
Helianthus annuus L. *803, 2592, 2850.*
Helianthus petiolaris Nutt. *856.*
Helianthus scaberrimus Ell. *184, 1025.*
Helianthus mollis Lam. *186.*
Helianthus grosseserratus Martens. *114, 1343.*
Helianthus hirsutus Raf. *407, 1023.*
Helianthus hirsutus, var. trachyphyllus T. & G. *1026.*
Helianthus tuberosus L. *2713.*
Helianthus tuberosus, var. subcanescens Gray. *1478, 2659.*
Actinomeris alternifolia (L.) DC. *322, 810, 3157.*
Verbesina virginica L. *310, 321.*
Verbesina helianthoides Michx. *864, 3752.*
Coreopsis tinctoria Nutt. *850, 2387, 2507.*
Coreopsis grandiflora Hogg. *179.*
Coreopsis pubescens Ell. *370, 371, 806, 849.*
Coreopsis palmata Nutt. *1030.*
Coreopsis tripteris L. *798, 2584.*
Bidens frondosa L. *853, 854, 855, 2692.*
Bidens cernua L. *1019, 1479.*
Bidens cernua, var. elliptica Wieg. *1018.*
Bidens bipinnata L. *309, 1017.*
Bidens aristosa (Michx.) Britton. *1480.*
Bidens involucrata (Nutt.) Britton. *180.*

Marshallia caespitosa Nutt. *2015, 2153.*
Helenium nudiflorum Nutt. *2315, 3233.*
Helenium autumnale L. *85, 1037, 3860.*
Helenium tenuifolium Nutt. *318, 3889.*
Dyssodia papposa (Vent.) Hitchc. *827, 3192.*
Achillea Millefolium L. *315.*
Anthemis Cotula L. *744.*
Matricaria suaveolens (Pursh) Buchenau. *2372, 4013.*
Chrysanthemum Leucanthemum L. *330, 3709, 3981.*
Tanacetum vulgare, var. incisum DC. *2548.*
Artemisia ludoviciana Nutt. *1027, 1028, 2747, 3473, 3874.*
Artemisia mexicana Willd. *906.*
Artemisia annua L. *1034.*
Erechtites hieracifolia (L.) Raf. *903.*
Cacalia atriplicifolia L. *868, 2598.*
Cacalia tuberosa Nutt. *534.*
Senecio obovatus, var. rotundus Britton. *859, 1342, 1667, 1834, 3521, 3669.*
Senecio plattensis Nutt. *314, 3383, 3942.*
Arctium minus Bernh. *858.*
Cirsium lanceolatum (L.) Hill. *2502.*
Cirsium discolor (Muhl.) Spreng. *3058.*
Cirsium altissimum (L.) Spreng. *189.*
Leptilon canadense (L.) Britton. *403, 769.*
Leptilon divaricatum (Michx.) Raf. *1169.*

Annals
of the
Missouri Botanical Garden

VOL. 3 NOVEMBER, 1916 No. 4

PISTILLARIA (SUBG. PISTILLINA) THAXTERI, BURT N. SP.[1]

THE SMALLEST KNOWN HYMENOMYCETE

EDWARD ANGUS BURT
Mycologist and Librarian to the Missouri Botanical Garden
Associate Professor in the Henry Shaw School of Botany of Washington University

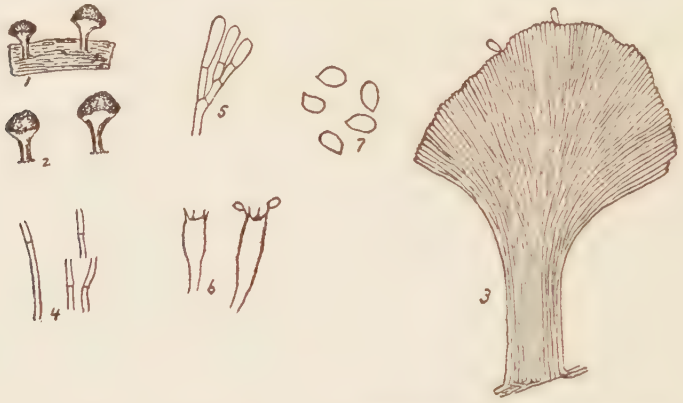
On a recent visit to the Mycological Herbarium of Harvard University, I was given for study by Professor Thaxter a curious fungus, collected at West Haven, Connecticut, in 1888. This fungus is a hymenomycete of very simple structure and exceedingly minute size — so minute that the fructifications are not visible to the naked eye unless rendered so by special illumination and background, as in the case of the dust particles of the air becoming visible in a beam of sunlight thrown across a darkened room.

By the aid of a lens the fructifications may be seen scattered on the surface of very rotten wood, merely gregarious, not united into clusters. One hundred and fifteen have been counted on an area 2 cm. long by ½ cm. broad. The fructifications, after being kept twenty-eight years in the herbarium, are whitish to cartridge-buff throughout; each has a subglobose head, the pileus supported on a slender stem, and in its form suggests the sporangium of a minute myxomycete, such as a *Physarum*. In figs. 1 and 2 are shown two fructifications under magnification of 63 diameters; in fig. 1 these fructifications were sketched in dry condition, as they were on the

[1] Issued January 12, 1917.

wood; in fig. 2 the same fructifications are shown after being removed from the wood and mounted in water.

The structure of the fructification is shown by the higher magnification of fig. 3. From a layer of hyphae at or near the surface of the substratum, hyphae start out together at right angles to the substratum and are closely joined in a



Pistillaria Thaxteri: 1, two fructifications in dried condition on wood, ×63; 2, the same fructifications in an aqueous mount, ×63; 3, median longitudinal optical section of a fructification, ×380; 4, hyphae, showing absence of clamp connections, ×640; 5, cluster of young basidia, ×640; 6, two basidia with sterigmata, ×640; 7, five basidiospores, ×640.

cylindric column about 60 μ long and 20–40 μ in diameter in the dried specimens, swelling to 25–50, and rarely 80 μ, in diameter when the specimens are wet, treated with potassium hydrate or lactic acid, and mounted in microscopical preparations. These hyphae are hyaline, thin-walled, about $1\frac{3}{4}$–2 μ in diameter, and not incrusted nor nodose-septate (fig. 4). At the outer end of the stem the hyphae pass into the pileus which is distinguishable from the stem by its obversely conical form, as shown under a magnification of 380 diameters in fig. 3. The obconical form of the pileus is due to repeated branching of its hyphae as they extend directly from the stem to the surface of the pileus. The manner of branching and of increase in diameter of the pileus is shown in figs. 3 and 5. At the outer peripheral end the terminal cell of each hyphal branch becomes swollen with pro-

toplasmic contents and differentiates into a simple basidium somewhat clavate in form, 13–17×4–4½ μ, when fully mature, which bears four spores upon short sterigmata (figs. 5 and 6). The spores are hyaline, even, slightly flattened on one side, pointed at the base, 5–9×3½ μ (fig. 7). No cystidia, hairs, or organs other than basidia have been found in the hymenium.

This fungus is remarkable not only for its minute size—and it is by far the smallest known species of the toadstool kind—but also for its extreme simplicity of structure. A few hyphae extend out together in a compact bundle from the vegetative mycelium, and at a little distance from the substratum simply branch and terminate in basidia bearing the usual basidiospores. No additional accessory, supporting, or secretory organs of any kind are differentiated, nor is there any perceptible differentiation into cortical and medullary regions in the fructification, nor any curvature of the fertile hyphae so that the basidia will be directed towards special cavities or towards the substratum; on the contrary, the whole fructification is as simple as a sheaf of wheat. A few hyphae stand out together from the substratum — probably for mutual support—and produce as simply and directly as possible their complement of basidia and basidiospores, and form both distinct stem and pileus of the simplest possible structure. The primordium of the pileus in its ontogeny in more highly developed species is not simpler.

Quelet[1] published under the name *Pistillina hyalina* Quelet, n. gen. and sp. the description of a fungus closely related to the American species which I am describing. *P. hyalina* is ten times as large as our fungus, clearly visible to the naked eye, and has elongated, aculeate spores. Quelet's genus *Pistillina* is regarded as a subgenus under *Pistillaria* of the *Clavariaceae* by Saccardo.[2] While *Pistillina* appears to be a needed genus for such species as that for which it was founded and for the present American species, still the few species

[1] Champ. Jura et Vosges, Suppl. 10, Assoc. Fr. Avanc. Sci. 9: 671. *pl. 8. f. 12.* 1880.

[2] Syll. Fung. 6: 759. 1888.

which would be clearly comprehended by it would be connected with the usual elongated forms of *Pistillaria* by some intermediate species found in Europe, where the species of *Pistillaria* appear to be more numerous and more frequent than in North America.

The present American species may be characterized as follows:

Pistillaria (subgen. **Pistillina**) **Thaxteri** Burt, n. sp.

Fructifications gregarious, pileate, erect, drying whitish to cartridge-buff; pileus hemispherical, puberulent, attenuated at the base into a cylindric stem composed of hyaline, thin-walled, even-walled, parallel hyphae about $1\frac{3}{4}$–2 μ in diameter, not nodose-septate, not incrusted; basidia simple, subclavate, 13–17×4–$4\frac{1}{2}$ μ, with four sterigmata; spores hyaline, even, flattened on one side, pointed at the base, 5–9×$3\frac{1}{2}$–$4\frac{1}{2}$ μ; no cystidia nor paraphyses.

Fructification 100–110 μ high; pileus 50–110 μ in diameter, 40–50 μ long; stem about 60 μ long, 20–50 μ, rarely 80 μ, in diameter.

On rotten wood, West Haven, Connecticut, November 7, 1888, *R. Thaxter*, type (in Farlow Herb. and Mo. Bot. Gard. Herb., 5724).

The fructifications are but a fraction of the size of those of any other species of the genus and not visible to the naked eye.

A NOTE ON THE ADAPTABILITY OF THE FOLIN MICRO-KJELDAHL APPARATUS FOR PLANT WORK

A. R. DAVIS
Formerly Research Assistant to the Missouri Botanical Garden

There is frequent need in most botanical laboratories for the determination of small amounts of nitrogen. Recourse is usually had to the familiar Kjeldahl method—a method, however, which proves rather cumbersome for certain types of work.

Within recent years Folin and Farmer[1] of the Harvard Medical School have modified the original Kjeldahl method to the end of determining small amounts of urea nitrogen. In their investigations they found the method approached the original in accuracy, while in economy of material to be analyzed, in reagents, and in time for determination, it was superior.

The Folin modification has been given an extended trial in this laboratory, and with a few modifications has been found admirably adapted to many phases of plant work. It is especially good for demonstration of proteolytic changes, since the determination of nitrogen in the different protein fractions can be readily made. The nitrogen content of minute plant sections or organs can be determined—as well as the effect of light, darkness, nutrition, disease, etc., upon the nitrogen content of various plant parts. The method is also adapted for work with advanced classes in plant physiology, the apparatus being easily set up, and requiring but little desk space and no hood; at the same time it is inexpensive to install.

Apparatus.—The essential parts of the apparatus are as follows:

1. Kjeldahl flasks of 100 or 200 cc. capacity;
2. Folin fume absorbers;[2]

[1] Folin, O., and Farmer, C. J. A new method for the determination of total nitrogen in urine. Jour. Biol. Chem. 11:493–501. 1912.

[2] These can be obtained at most laboratory supply houses.

3. Micro-burners;
4. Ostwald pipettes of 1 and 2 cc. capacity;
5. Condensers of small size.[1]

The fume absorption apparatus consists of two parts: (1) a piece of straight glass tubing with side arms, (2) the fume absorber proper. This latter is a 25-cc. pipette, one end of which is invaginated into the bulb, the other bent midway at a little more than right angles. The invaginated end sits into the neck of the digestion flask, while the other end fits into a side arm of the glass tubing. The latter, in turn, connects to the suction pump, by which the fumes are drawn off. Both the Kjeldahl flasks and the tubing are supported in the manner illustrated in pl. 7.

In the Folin modification, Jena test-tubes (200×25 mm.) are used in digestion. In this laboratory the small Kjeldahl flask has been found to be better adapted to plant material, because of the relatively high percentage of carbohydrates present, and the tendency of these to froth.

The material, if in solution, is added to the digestion flask by means of a calibrated Ostwald pipette; if in solid form, as plant organs or sections, it is carefully dried and weighed. The quantity of material taken for digestion must be determined by a preliminary rough analysis, since the method is best adapted for amounts of nitrogen between .5 and 5 mg. One cc. (more if needed) of chemically pure sulphuric acid (conc.) is added to the material to be digested, the amount depending upon the quantity of carbon-containing compounds present, then 1 gram of potassium sulphate and a drop of 5 per cent copper sulphate. The contents are heated slowly until frothing is over, after which a hotter flame may be employed. Sometimes it is necessary to add some solid fragment to prevent bumping, a bit of unglazed porcelain being especially good. Small mica chimneys can be obtained to protect the flames from air currents, but lacking these bottomless beakers may be used.

Upon completion of digestion the contents of the flask are permitted to cool somewhat (the liquid must not become

[1] The condensers can be made in the laboratory from glass tubing.

solid), then 50 cc. of ammonia-free water carefully added. Folin removed the nitrogen by adding saturated NaOH to alkalinity, then forcing the ammonia over into standard acid with a vigorous air current. While the method is excellent with the small amount of water used in the Jena tube, it does not give good results with the Kjeldahl flask and the larger amount of water used there. Distillation is more efficient.

Small condenser tubes were made in the laboratory from glass tubing, the outer jacket measuring 40×2 cm., and the inner 5 mm. in diameter. The lower end of this latter, where it dipped into the collection acid, was fitted with a larger tube 14 mm. in diameter—this to prevent back-flow of the acid; to the upper end of the inner tube was attached a safety trap made from a 10-cc. pipette, which, in turn, fitted into the Kjeldahl flask by means of a two-hole rubber stopper. Through the second hole of this was inserted a small piece of glass tubing closed at the upper end with a bit of rubber tubing and a pinch clamp, thus making it possible to add the alkali after the apparatus had been connected up for distillation. The distillation is carried on in the usual way. It is commonly necessary to add a pinch of zinc dust to the distilling mixture to prevent bumping, while a few drops of liquid paraffin will keep down a tendency to froth. The ammonia is collected in N/20 acid and titrated against alkali of the same strength. Alizarin red (Alizarin sulfonsäure Natrium, Merck) in .1 per cent aqueous solution gave best satisfaction as an indicator.

Folin has chiefly employed the colorimeter for the actual determination of nitrogen. The method has its distinct advantages, especially if the precautions indicated by Folin are observed in Nesslerizing. In the absence of a colorimeter, however, and because excellent results were always obtained in our work by titration, the latter method has been retained.

The following tables show how the results obtained with the "micro"-method approximate very closely those gotten with larger amounts of material in the original Kjeldahl. The illustration is that of an ordinary laboratory experiment

showing some of the steps involved in the enzymic hydrolysis of albumin.

Papain (.1 gm.) was added to 200 cc. 2.5 per cent albumin solution, alkalinity reduced to N/250, then incubated at 40°C. for two hours. Portions were removed and tested both with the "micro"- and the "macro"-Kjeldahl for proteolytic change. One cc. was digested with the former, 15 cc. were used with the latter.

TABLE I

NITROGEN DETERMINATIONS IN THE HYDROLYSIS OF ALBUMIN

Nitrogen fractions	Micro-Kjeldahl				Macro-Kjeldahl	
	Albumin +enzyme	Albumin +water	Albumin +enzyme	Albumin +water	Albumin +enzyme	Albumin +water
	in 1 cc.		calc. to 15 cc.		in 15 cc.	
	mg.	mg.	mg.	mg.	mg.	mg.
Total nitrogen....	3.80	3.795	57.00	56.925	57.675	57.500
Coagulable nitrogen.....	.913	3.145	13.695	47.175	14.125	48.225
Phosphotungstate ppt.....	1.397	.472	20.955	7.080	21.275	6.925
Amino acids and NH_4.....	1.490	.177	22.35	2.655	22.5025	2.785

Further comparison is made in the recovery of nitrogen from a carefully prepared solution of $(NH_4)_2SO_4$. As before, 1 cc. of solution was used with the "micro"- and 15 cc. with the "macro"-Kjeldahl.

TABLE II

THE RECOVERY OF NITROGEN FROM A SOLUTION OF $(NH_4)_2SO_4$ CONTAINING 3.217 MGS. PER CC.

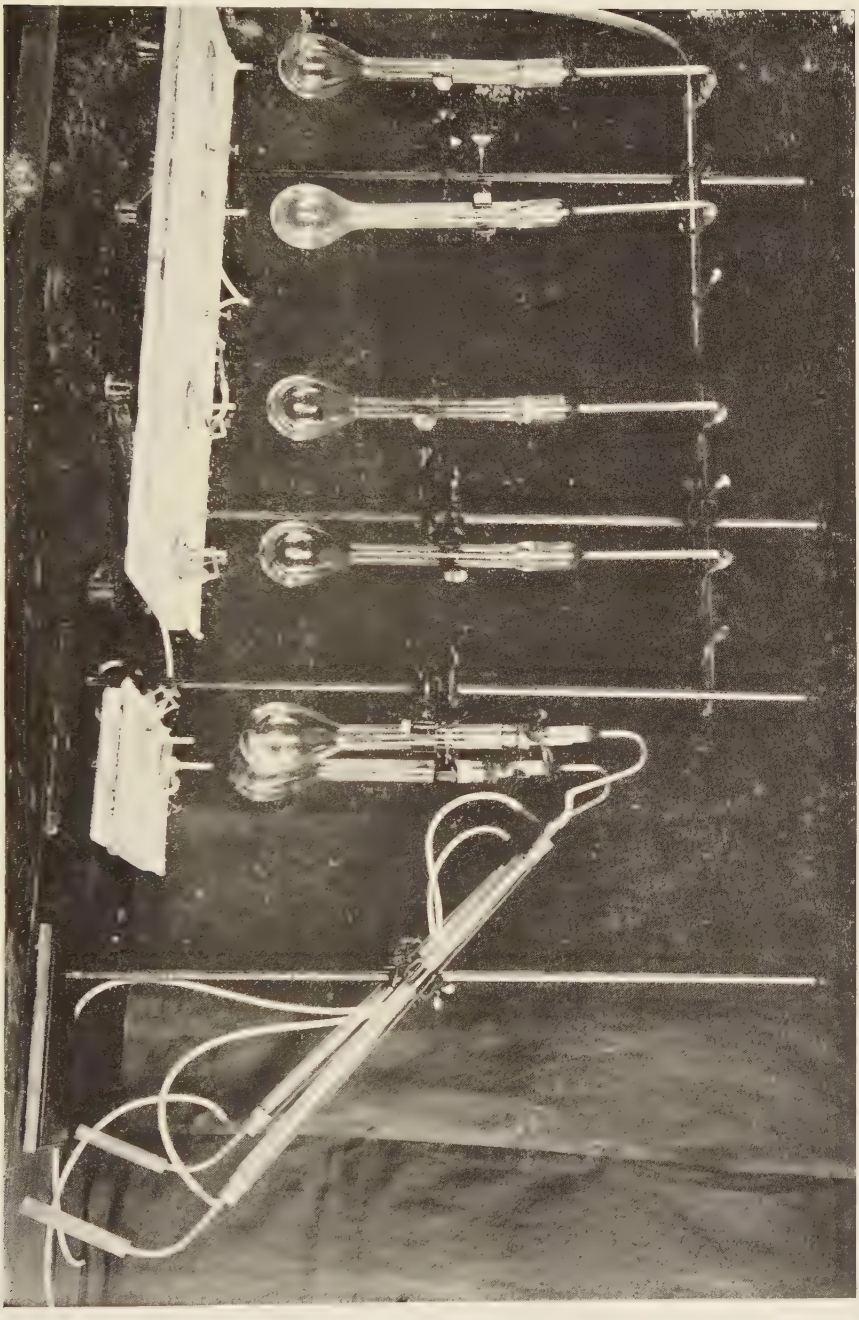
Exp. no.	Micro-Kjeldahl, 1 cc. solution used		Macro-Kjeldahl 15 cc. solution used
	Found	Calculated for 15 cc.	Found
	mg.	mg.	mg.
1	3.13	46.95	47.595
2	3.12	46.80	48.125
3	3.17	47.55	46.925
4	3.185	47.775	45.400
5	3.192	47.880	47.3925
Theoretical	3.217	48.255	48.255

Graduate Laboratory, Missouri Botanical Garden.

Explanation of Plate

PLATE 7

Folin's micro-Kjeldahl apparatus for the determination of nitrogen.



DAVIS—FOLIN MICRO-KJELDAHL APPARATUS

STUDIES IN THE PHYSIOLOGY OF THE FUNGI[1]

I. Nitrogen Fixation

B. M. DUGGAR
Physiologist to the Missouri Botanical Garden, in Charge of Graduate Laboratory
Professor of Plant Physiology in the Henry Shaw School of Botany of Washington University

AND A. R. DAVIS
Formerly Research Assistant to the Missouri Botanical Garden

Introduction and Critical Review of Literature

The problem of the fixation of free (atmospheric) or molecular nitrogen by the fungi has received attention at the hands of no small number of investigators, yet a careful study of the literature is sufficient to indicate that much further work —with the strictest regards for accurate methods—will be required before the problem is satisfactorily solved. For reasons developed later in this paper, we have felt the desirability of continuing, under different conditions, the investigations begun by one of us some years ago.

At the present time there can be no doubt entertained, of course, as to the capacity of the legume tubercle bacteria (*Bacillus radicicola* vars.) and certain soil forms (notably *Azotobacter spp.* and *Clostridium Pasteurianum*) to fix nitrogen. Here the amounts of nitrogen-increase in relatively small cultures under favorable conditions are so far above any regular experimental errors, and so consistently reported by careful workers, that the simple question of whether or not there is fixation is eliminated. On the other hand, there is much contradictory evidence as to the fact of nitrogen fixation by other bacteria and by the fungi, especially by the moulds and

[1] Note.—About half a dozen investigations are already in progress dealing with the physiology of the fungi, and it is proposed to give considerable attention to this phase of physiology during the next few years. The investigations would include certain aspects of nutrition and enzyme action, growth relations—especially the effects of environmental factors—and various phases of the general phenomenon of parasitism. On account of the continuity or relationship of many of the problems, it has seemed well to group these topics under the general title "Studies in the Physiology of the Fungi," of which the present article is No. 1. —B. M. Duggar.

other saprophytic species. Even those who report fixation for the last-mentioned fungi base their conclusions, in the majority of cases, upon amounts which are only questionably beyond the possibility of experimental error. The literature has been frequently reviewed, but for purposes of discussion in this and in forthcoming papers, it has been found well to give this detailed consideration. No account of N-fixation by bacteria is included.

The experiments of Jodin ('62) are now interesting merely in an historical way. He observed fungi, in an impure culture, to grow upon media, "très sensiblement exemptes de composés azotés organique ou mineraux." Employing the methods of gas analysis, he found that in a sealed vessel the amount of molecular nitrogen used was from 6 to 7 per cent of the oxygen consumed.

Hallier ('67) simply reported that he had often observed yeasts growing in a nitrogen-free medium, but he realized the necessity of quantitative data in order definitely to determine the fact of nitrogen fixation. From observations on the growth of mould fungi in nitrogen-containing and nitrogen-free media Nägeli ('80) concluded that mould fungi are unable to assimilate free nitrogen.

Frank ('92) states that he grew certain forms of *Penicillium* upon nutrient media lacking nitrogen and then tested the media for the presence of nitrogen, securing a positive indication. No quantitative work appears to have been done, nor are the quantities of medium employed in either case mentioned. Later he ('93) reported growing *Penicillium cladosporioides*[1] (=*Hormodendron cladosporioides*) during ten months in nitrogen-free media containing sugar. A culture on 65 cc. of solution is reported to have given a fixation of 3.5 mg. nitrogen. Insufficient details are furnished regarding methods employed and the use of controls.

Using *Aspergillus niger* and *Alternaria tenuis* as the basis of a test, supplementary to a more complete study of bacteria, Berthelot ('93) reported a fixation of 5.8 to 10.0 mg. in the

[1] In the discussion of literature the writers have written the names of the various organisms just as they are given in the original articles.

first-mentioned fungus, and 4.6 to 11.1 mg. in the last-named species. This appears to be the total amount fixed after growing for a period of months in 600 cc. of Cohn's solution with various sources of carbon. For 100 cc. the nitrogen quantities would therefore be .97–1.67 and .77–1.85 mg., respectively. Fixation by *Gymnoascus* is also mentioned. With respect to analytical methods the exact procedure is not given, and one might, perhaps, without being too critical, wish to have had assurances regarding the purity of cultures, the nature of the vessels ("ballons") used, and how the sample for analysis was taken, especially in view of the following remark made in regard to the amount of fixation in one of the series with bacteria: "Ils auraient été sans doute plus accusés si la dessiccation des matériaux n'avait pas fini par amener la mort des bactéries."

Puriewitsch ('95) used *Aspergillus niger* and *Penicillium glaucum* in a nutrient salt solution containing also 3 per cent tartaric acid, variable amounts of cane sugar, also small amounts of ammonium nitrate. He obtained a mean nitrogen fixation of 4.51 mg. for *Aspergillus,* and 3.26 mg. for *Penicillium.* It is not stated whether these amounts are calculated on the basis of 100 cc. of solution, or whether they were for 25–50 cc., the quantities which appear to have been used in the different cultures. At the same time he reported that the amount of fixation increased with the concentration of sugar, but did not increase in direct proportion to the increase in weight of the mycelium. It is not clear, though quite possible, that these results were obtained with pure cultures. Moreover, since in some of the cultures, at least, dry weight determinations of the fungous felt were made, the conclusion is unavoidable that herein might be a possibility of error. Likewise, the division of some of the experiments into "(a)" and "(b)" suggests that the whole of the solution was not employed in the analysis. The results were subsequently criticized by Czapek ('01) and Heinze ('06) on other grounds.

The fact that fungi may make an appreciable growth on media containing a very low minimum of nitrogen, without nitrogen gain, has been pointed out by some investigators,

and may adequately explain Fermi's ('96) statement to the effect that he was able to grow certain moulds and yeasts on nitrogen-free media without nitrogen fixation.

Brefeld ('00) determined that cereals and grasses infected with species of *Ustilago* were unable to assimilate free nitrogen, but this type of negative evidence is valueless in the present discussion.

More extensive than any of the earlier work is that reported by Saida ('01) who investigated seven species, three of which (*Phoma Betae, Mucor stolonifer,* and *Aspergillus niger*) give nitrogen fixation both with and without the presence of combined nitrogen in the culture medium, one species (*Endococcus purpurascens*) requires the presence of combined nitrogen, and three species give negative results. In most cases the fungi were grown on 50 cc. of nutrient salt solutions containing dextrose or cane sugar, the source of nitrogen being a small quantity of $(NH_4)_2SO_4$ or of $(NH_4)_2CO_3$. In none of the four species except *Phoma Betae* is the amount of fixation more than about 2 mg. (.8871–2.0699 mg.). Fixation (varying from 1.1828 to 10.536 mg.) in *P. Betae* rises somewhat in relation to sugar content of the medium, although maximum fixation occurs in sugar beet decoction plus sugar. The exact method of handling the cultures is not described, but with the exception of possibilities mentioned later, the work seems to be above criticism.

Czapek ('01) states that *Aspergillus niger* does not fix free nitrogen. Later, as a result of numerous experiments on nitrogen-containing media Czapek ('02) again reports no fixation for this species. He declares that the work of Puriewitsch and Saida requires confirmation.

Studying the effects of a yeast and a mould on the nitrogen fixation of *Azotobacter,* Gerlach and Vogel ('03) conclude from analyses of the control cultures, in which each of these organisms was grown alone, that neither of the former fungi are capable of utilizing atmospheric nitrogen.

Koch ('03) was unable to demonstrate any nitrogen fixation for *Aspergillus niger* in a few preliminary experiments. He draws attention, however, to an experiment made by

Hiltner from which it would appear that *Lolium temulentum* (inhabited by an associated fungus) thrives equally well in quartz sand with or without nitrogen as fertilizer, while the fungus-free *Lolium italicum* develops much better when the quartz sand is fertilized with nitrogen than when the substratum is without such fertilization.

In the first experiments reported by Ternetz ('04) with the fungus isolated from the roots of certain *Ericaceae,* and later designated *Phoma radicis* vars., very slight nitrogen fixation was found. In 100–150 cc. of nutrient solutions containing dextrose .6–3.85 mg. represent the range of fixation.

Stimulated by the work of Saida and others, Heinze ('06) reports a detailed repetition of the work of Saida ('01) and Puriewitsch ('95), employing to a considerable extent the same organisms and the same solutions. The work seems to have been unusually extensive, but since it was in every case negative, no details are published. Heinze was apparently inclined in 1903 to consider the possibility that yeasts in certain stages may fix nitrogen, since he states (see review of Schulze's work by Heinze, Centralbl. f. Bakt. II. **10**: p. 675): "Schliesslich deuten mancherlei Beobachtungen der Ref. darauf hin, dass man auch event. bei den Hefen—und zwar in statu sporulandi—möglicherweise gerade bei den Vorgängen, bei denen die Spore nach Hansen wiederum zum Sporangium wird, mit gewissen mehr oder weniger stark ausgeprägten N-Assimilationsvorgängen zu rechnen hat." This earlier statement is apparently the basis of Lipman's ('11–'12, see p. 173) reference to Heinze's work.

Through pot experiments with seedlings of *Pinus montana* with and without mycorhiza, Möller ('06) concluded that the fungus associated with the roots of this species is unable to supply the host with nitrogen accruing as a result of fixation.

In continuation of her earlier work Ternetz ('07) has secured data of special interest, with reference to fixation, for *Phoma radicis* vars., likewise in a comparative way for a few other fungi and bacteria. The utmost care seems to have been observed with respect to the purity of materials, the use of necessary blanks in the analyses, and of controls in the

experiments. Cultivated during a period of 28 days on 50 cc. of nutrient solution the 5 races of *Phoma radicis* gave a nitrogen fixation ranging from 2.3 mg. in the lowest to 15.7 mg. in the highest. For *Aspergillus niger* and *Penicillium glaucum* the fixation was 1.9 and 2.8 mg., respectively. The usual high fixation was secured with *Azotobacter chroococcum* and *Clostridium pastorianum*. In spite of the fact that the methods employed are those generally recognized as unimpeachable, still attention should be drawn to the fact that in such cases as those of *Aspergillus* and *Penicillium*, where the fixation is only about 2 mg., the technique employed must be subjected to the closest scrutiny. It is noted that the felt was separated from the culture solution in the usual way, and further that the solution was then made up to the original volume (a procedure of vital importance when aliquot parts of the solution serve for analysis, and one seldom mentioned). Then from one-sixteenth to one-fourth, depending upon the amount of sugar present, of the total solution was taken for the analysis. In this way any small experimental error involved would have been multiplied 4–16 times.

Equally satisfactory in respect to method is the work of Froehlich ('08). Here again the methods are described in sufficient detail so that one is not left in doubt as to important parts of the technique. The organisms used lend a particular interest to the work, inasmuch as they were isolated from dead and decaying plant material and are fungi generally considered important in the decay of vegetation. Those selected consist of one species from each of four common genera. All were found to fix nitrogen to a slight degree, averaging as follows: *Alternaria* 3.34, *Macrosporium* 3.70, *Cladosporium* 2.26, and *Hormodendron* 1.93 mg. Many subsidiary experiments of interest are included.

Zikes ('09) conducted extensive experiments to determine the free nitrogen relations of a yeast-like organism isolated from the leaves of laurel and called by him *Torula Wiesneri*, which he cultivated on flasks containing 300 cc. of culture fluid. He employed the Dumas method of analysis, filtered off the fluid from the yeast cells, and made separate determina-

tions. He reports a fixation of 5.1–6.5 mg. per liter, .51–.61 per 100 cc. of culture solution, which, however, he regards as satisfactory positive evidence.

No investigator has obtained figures comparable to those of Latham ('09). This work was well conceived and arranged with a view to determining the effect of zinc sulphate on the nitrogen fixation of *Sterigmatocystis nigra* (*Aspergillus niger*) abundantly supplied with combined nitrogen.[1] The results published exhibit a variation ranging from a nitrogen loss of 42.5 mg. to a fixation of 205.1 mg. per culture, on 50 cc. of medium. In view of all the earlier and later studies made on fixation by this fungus, granting at the same time, of course, possible differences in strains, it can only be surmised, perhaps, that miscalculations are accountable for these unusual results. It would appear that in making the analyses she employed aliquot parts of the culture solution, and likewise divided the felt. Such a procedure, however, only suggests possibilities and cannot explain the results. In the case of maximum fixation, 677.3 mg. of nitrogen are reported fixed in felt and solution per gram of dry felt produced. This is an amount incomparably greater than anything elsewhere obtained.

Duggar and Knudson ('11) reported only by abstract upon extensive series of experiments in which *Aspergillus niger*, *Trichoderma lignorum* (erroneously given as *T. lignicola*), and several species of *Basidiomycetes* were employed. Various nutrient media were used, including synthetic nutrient solutions, leaf decoctions, and decayed leaves ground to a fine powder. None of the cultures showed a difference in the N-content over the controls sufficient to indicate fixation, whether with or without combined nitrogen. It may be stated that this work was not published in detail by reason of the uniformly negative results. It was intended to pursue the work further using ground leaf mould and similar materials as nutrient media, but difficulties in obtaining uniform samples

[1] The nutrient salt solution employed was the well-known Richards' solution consisting of NH_4NO_3 1 gm., KH_2PO_4 0.5 gm., $MgSO_4$ 0.25 gm., $FeCl_3$ trace, and sugar 5 gm., except that the amount of the nitrate in the different series varied from 115.4 to 160.3 mg. per culture, or 50 cc. of solution.

for analysis on such media were almost insuperable. The desirability of growing the *Basidiomycetes* on solid media was obvious, but under such circumstances it would have been necessary for greatest accuracy either to analyze the entire contents of such bulky cultures or to take account of change in weight of materials due to loss of CO_2 and H_2O produced in respiration.

Löhnis ('10) seems to report having found N-fixation in *Torula,* but his work was neither extensive nor reported in such way as to give the details of the methods employed.

Pennington ('11) worked with two species of *Penicillium,* two species of *Fusarium, Aspergillus niger,* and *Alternaria sp.* A variety of experiments was arranged in liter flasks containing 100 cc. of solution. Employing accepted methods he obtained no nitrogen fixation in a first series of experiments, although there was some growth on media practically without nitrogen, that is, with scarcely perceptible amounts, due, he believes, to impurities in the dextrose employed. In another extensive series no differences between the flasks containing the moulds and the controls were sufficient to indicate fixation. In one case *Penicillium* gave an apparent fixation of .88 mg. In considerable part his work was planned to confirm or disprove that of Latham ('09). The results are therefore peculiarly interesting, especially as he has apparently observed great care to eliminate all possibilities of error, and in advance thoroughly tested his ability to determine the nitrogen content of the cultures accurately.

Medisch ('10) observed some growth of the fungus *Hypocrea rufa* in solutions to which no nitrogen was added. He reports a gain of 1.05–2.45 mg. nitrogen in 50 cc. distilled water. This preliminary experiment was followed by others in which, under purified air, the organism was grown on various culture solutions. These included solutions containing no nitrogen, nitrogen as "potassium humate," and as NH_4NO_3. The results indicate that, whereas in the first case, with nitrogen present only as an impurity, the fixation was 1.74–3.23 mg. in 100 cc., in the humate solution the gain was 3.15–4.61 mg., and in the solution containing NH_4NO_3 the gain was

2.45–3.06 mg. He considers these quantities as possibly within the limit of experimental error. Unfortunately, various details regarding the handling of cultures and the methods of analysis are omitted.

Lipman ('11–'12) made an extended study of the relation of certain yeasts and fungi to nitrogen fixation, employing 7 species of yeast, 5 pseudo yeasts, and *Mycoderma,* also *Aspergillus niger, Penicillium glaucum,* and *Botrytis cinerea.* In the first extensive series, omitting the moulds, there was a slight gain of nitrogen in practically all cases, but only in a single case, a pseudo yeast, was this more than 1.0 mg. In a second series 9 out of 15 forms gave a gain of 1.05–2.28 mg., while 6 forms yielded less than 1 mg. increase of nitrogen. In the final series, which includes the fungi, the yeasts exhibited gains of .07–3.78 mg., while the fungi ranged from .05 to 2.38 mg.

Preliminary to her studies in nitrogen fixation Stahel ('11) made an extensive trial of fungi on media low in nitrogen. She isolated 54 species, largely from decaying vegetation, and then grew these on various media, including silica jelly without combined nitrogen. Five species were found to grow well on the last-named medium, while 22 made some growth. In the studies regarding N-fixation it is determined that the 5 species which grew on nitrogen-free media are capable of fixation, likewise 4 of the organisms from the group growing indifferently also possess this capacity. The method of handling the flasks is not given in detail, but it appears that the mycelium was filtered off from the solution and separate analyses made. The fungi were grown on 200 cc. of nutrient solution, and, in general, the amount of fixation was related to the initial nitrogen content. While the method suggests some possibilities for error, yet in some cases the amount of fixation is certainly well above the usual experimental errors. It is to be noted, however, that the following amounts represent questionable fixation: *Aspergillus* .41 mg., *Penicillium* .50 mg., *Botrytis* .46 mg., *Melanoma* .46 mg., *Epicoccum* .41 mg., *Bispora* .61–1.44 mg.; while the following give higher re-

sults: *Alternaria* 1.02–5.55 mg., *Hormodendron* .36–5.0 mg., *Macrosporium* .23–5.91 mg.

Experiments conducted by Kossowicz ('12) which seemed to suggest N-fixation in the case of certain species of *Saccharomyces, Monilia candida,* and *Oidium lactis* were subsequently repeated by him ('14) under more nearly standard control conditions. The results were interpreted as entirely negative. Besides the organisms previously employed, he used also *Aspergillus niger, A. glaucus, Penicillium glaucum, P. brevicaule,* and a species of each of the following, *Botrytis, Mucor,* and *Isaria.*

Will ('12), reporting work of Scheckenbach, declared the capacity of certain species of *Torula* to grow upon nutrient media lacking nitrogen, likewise to fix atmospheric nitrogen when little or no combined nitrogen was supplied. There is, however, with the experiments reported, little evidence that sufficient precautions were taken in the arrangement of suitable controls.

The capacity of *Blastoderma salminicolor, Torula sp.,* and "pastorianus" yeast to fix nitrogen has been mentioned by Lindner ('12),[1] but to what extent this work was quantitatively executed cannot be determined from the data at hand.

Goddard's ('13) investigations parallel those of Froehlich, Stahel, and, to a certain extent, those of Ternetz. He isolated 15 species of fungi from the soil, and tested each of these with respect to nitrogen fixation, grown on 50 cc. of a culture solution comparable to the nutrient media employed by other investigators. Every possible precaution seems to have been taken to insure accuracy. The fungi were grown 48–70 days. With no organism in any series were there indications of consistent gains over the initial nitrogen content. Species of *Aspergillus* and *Penicillium* were included in these studies.

In connection with his investigations of mycorhiza problems, Peklo ('13) isolated 3 species of fungi, 2 being species of *Penicillium,* and one an indetermined form. Each of these was grown on Winogradski's solution plus dextrose for 1–2

[1] The reference given appears to be an abstract of a more extensive report which is at present unavailable.

months. For each species he claims positive results, the fixation ranging from 0.8575 mg. in the lowest to 1.8615 mg. in the highest, per 100 cc. of solution. The inference seems to be that in each case a single inoculated culture or a single control was usually employed. It is of interest to note that aside from the few analyses made, the fungous felt and the solution were separately analyzed.

Traaen ('14) made no quantitative studies to determine N-fixation, but he observed the growth of 4 fungi on media practically nitrogen-free, and as a result of the very weak growth he came to the conclusion that under the conditions they could not possibly utilize atmospheric nitrogen.

Using strains of *Aspergillus niger* and *Penicillium glaucum,* Chambers ('16) was unable to demonstrate any N-fixation. He employed Folin's micro-Kjeldahl method, growing the organisms in long Jena test-tubes and making the determinations without transfer of any portion of the culture.

Methods

The organisms used in this work were *Aspergillus niger,* a strain long employed in various physiological experiments in this laboratory; a species of *Penicillium,* isolated from leaves and corresponding closely to Thom's idea of *P. expansum; P. digitatum,* isolated from a decaying orange; *Macrosporium commune,*[1] isolated from dried grass culms; *Phoma Betae,* a culture obtained through the kindness of Mr. E. C. Rittue, Los Angeles, California; and for comparison three forms of *Azotobacter,* as follows, all three being furnished by Dr. J. G. Lipman, *A. vinelandii, A. chroococcum* (from Kansas soil), and *A. chroococcum* (from Colorado soil).

Except as to the source of nitrogen and carbon, there has been no great dissimilarity in the mineral nutrient solutions employed by European investigators. The Cohn solution or a modification of it has been the basis of much of the foreign work. We wished to have some of our experiments follow fairly closely the work of Saida, therefore we have used in

[1] The morphological and cultural characters of this organism will be described in a subsequent paper.

some of the experiments (series 1A–4A, table 1) his solution as regards concentration of mineral nutrients. It is as follows:

KH_2PO_4	.4 gram	This is designated solution A.
$MgSO_4$	.4 gram	
$CaCl_2$	.2 gram	
H_2O	100 cc.	

To this has been added $(NH_4)_2SO_4$ or asparagin as a source of nitrogen, and dextrose or saccharose as a source of carbon. In most of the work, however (series 5B–15B, 17B–22B, table 1), it has seemed well to use a modification of the formula known as Richards' solution, used especially by Miss Latham in securing the extraordinary results to be referred to later. The modification consists merely in varying the sources and amounts of nitrogen and carbon furnished, these last being the same as employed with "solution A" above.

The Richards' solution consisted of:

KH_2PO_4	.5 gram	This is designated solution B.
$MgSO_4$	.25 gram	
$FeCl_3$	trace	
H_2O	100 cc.	

Stock solutions of each constituent were made up of appropriate strength, usually such that an equal quantity of each was required for any culture.

For *Glomerella Gossypii* a modification of the Uschinsky solution, as indicated in table 1, was employed, since this had been found satisfactory for this organism through other workers in the laboratory. For the various strains of *Azotobacter* a soil-compost extract containing mannite was employed. Three hundred gm. of potting soil and 100 gm. of well-fermented compost were each extracted for 2 hours with 1 liter of water, then filtered, and the filtrates combined. To the mixed extract was added for each 100 cc. the following constituents: K_2HPO_4 .05 gm., $CaCO_3$ 1 gm., and mannite 5.0 gm.

Kjeldahl flasks of 500 cc. capacity were used as culture vessels in all cases, and into each were placed 50 cc. of the solution required.[1] The idea of using the Kjeldahl flasks for the cul-

[1] In the bacterial cultures 100 cc. of solution were employed.

tures enabled us to make the nitrogen determinations of both inoculated and uninoculated flasks from the entire contents of the flasks, therefore to dispense entirely with any transfers of culture solution or fungous felt, and to avoid the possibility of errors thus ensuing.

All glassware was cleaned by standard methods; nitrogen-free double distilled water was used; and Merck's reagents. Every experiment was set up in triplicate, also with three controls; that is, for every series in which a different fungus, a different amount or source of nitrogen or of carbon was used, there were 6 cultures, 3 of which were inoculated and incubated, while the remaining 3 were inoculated, autoclaved to kill the spores (since they served as controls), and were then incubated with the others.

The inoculations were made from cultures on potato agar, fresh cultures only being employed as a source of spores or mycelium. The inoculation procedure was as follows for those forms producing spores: Numerous spores were transferred to a flask containing 100 cc. sterile H_2O. This was agitated until there was an evident spore suspension, and this then pipetted out with a sterile pipette into a second sterile flask. From this last flask 1-cc. portions were transferred with sterile pipettes to each flask in the series. The controls were then autoclaved for 15 minutes at 15 pounds pressure. That the method was entirely satisfactory is shown by the fact that there was only a single case of contamination in all the series employed and no case of growth in any of the controls. Similarly, in the inoculation of the series with *Azotobacter,* loops of the organism were diffused in sterile water, then $\frac{1}{5}$-cc. portions were placed in each flask by means of a sterile graduated pipette. All transfers were made with the greatest precaution in a steamed transfer room. In the case of *Phoma Betae,* where no spores were produced, small masses of hyphae of approximately equal size were inserted into each flask.

Repeated tests have shown that in the incubator rooms for the length of time which these experiments were permitted to run there is no detectable amount of combined nitrogen absorbed by flasks of the culture solution or by flasks of dis-

tilled water. Both from this fact and further from the nature of the controls it was unnecessary to place the cultures in a chamber arranged to protect against combined nitrogen.

The data presented in this paper on the determination of nitrogen were obtained either with the Kjeldahl-Gunning method,—using mercury in addition to potassium sulphate,—or, where nitrates were involved, with the Förster modification of the method mentioned. In some preliminary work an extended attempt was made to utilize the Folin micro-Kjeldahl apparatus, but that proved inapplicable to the present work for the following reason: The amount of culture solution which it is possible to use with this method is small, and doubtless would be too small to yield convincing results in view of the present confusion regarding the question of nitrogen fixation in the fungi. In the light of the results obtained by Puriewitsch, Saida, and others, all of whom used from 50 to 100 cc. of culture solution, it seemed essential to employ the "macro" method and to deal with cultures as large as practicable.

In the pioneer work of Jodin ('62) gas analysis methods were employed for the determination of nitrogen fixation, therefore through the indirect method of nitrogen loss in the culture chamber. Since that time all the work which may claim a right to be considered quantitative has been made with the Kjeldahl method, or with some modification of it, usually the Gunning. That this method is sufficiently accurate to detect any amount of fixation worthy of the name is evident, since an experienced analyst can usually secure results which often check to within .2 mg. However, if one does not observe all possible precautions, errors may creep in which will yield widely varying results. Chief among these possibilities in the problem of nitrogen fixation are the following:

1. Impure chemicals.
2. Accuracy of standard acid and alkali.
3. Indicator.
4. Completeness of digestion and distillation.
5. Loss of nitrogen in the transfer of the culture material, or felt, from one flask to another.

6. Multiplication of the experimental error through taking an aliquot part of the fungous mat or culture solution and upon the determination from this basing a calculation for the whole.

7. Inadequate controls.

Analyzed chemicals may be obtained always, but these should be checked by running blank experiments. Standard acids and alkalis should be checked up by at least two methods. Nevertheless, slight discrepancy in the standard affects the actual rather than the relative analytical results, provided the same solutions are used for the nitrogen determinations whether they grow the fungus or are used as controls. Certain indicators have, in the presence of ammonia, what might be called a "running" end-point; that is, the color change occurs through a fairly wide range of H-ion concentration. After trying several indicators for this work alizarin red (Alizarin sulfonsäure Natrium, Merck) and cochineal were found to give the best satisfaction. The former in .1 per cent aqueous solution was used.

The error due to incomplete digestion or distillation, while easily guarded against, may sometimes occur, if care is not observed. It was the practice here to continue the digestion 15 minutes after the mixture had become colorless. A full hour was given to distillation, since this interval proved entirely sufficient as shown by tests from time to time.

In the critical review of literature it has been emphasized that many of those investigators reporting nitrogen fixation for the fungi have limited their nitrogen determinations to aliquot portions of the culture solution. The total nitrogen was then calculated. Summarizing some of the points to which attention should be drawn, it is found that Puriewitsch ('95), Saida ('01), Ternetz ('07), and Froehlich ('08) all filtered the solution from the fungous mat, determined the nitrogen from a portion of the solution, and calculated for the whole solution. The mat nitrogen was determined separately. Stahel ('11), Peklo ('13), and others, after separating solution from fungous felt, evaporated the culture medium to small bulk (following the addition of acid) and determined the

total nitrogen. To this was added the amount of nitrogen found in the felt. Lipman ('11–'12) did not separate the mat from the medium, but transferred the whole to a digestion flask, and later to a distilling flask, determining the total nitrogen in one lot. All the cases cited above involved one or more transfers of material, since the fungi were usually grown in Erlenmeyer flasks or similar receptacles, and the contents filtered or transferred before digestion, thence usually a second transfer to a distilling flask. It was with the end in view of eliminating the possibility of error in this direction that the method already described was employed, i. e., of growing, digesting, and distilling in the same flask and without transfer.

Where the digestion of nitrates was involved in the culture solution, the previous investigators have used, almost without exception, the Gunning-Jodlbauer method—phenol or salicylic acid and zinc dust being employed for the reduction of nitrates. In our work the Förster modification was employed, since certain workers have found difficulty in obtaining all the nitrate by the former method. Indeed, it was this difficulty which first led Förster to use sodium thiosulphate as a reducing agent. If all nitrates are not reduced a serious error is, of course, involved, one which, moreover, makes for a difference between controls and inoculated flasks. The results may be presumably correct for the converted or assimilated nitrogen of the mycelium (or products excreted therefrom), low figures resulting for the nitrate of the culture media. If an error were present, then, it would be related somewhat closely to total growth or to sugar consumption, factors determining nitrate consumption. It is equally true that the capacity to fix nitrogen by a fungus, if possible, might also be related to the capacity for growth under the particular conditions.

In the use of the Förster method at first certain difficulties were experienced. In preliminary work the recovery of nitrogen from a water solution of KNO_3 was easily accomplished within experimental error. When, however, a nitrate was added to a soil, compost, or plant tissue decoction the results were invariably low. It was found necessary to add

more sodium thiosulphate (3 gm. instead of 2) and to allow 10–15 minutes after its apparent decomposition had taken place before digestion was continued. This illustrates the possibility of error in a method that is not thoroughly tested in connection with the peculiar conditions at hand.

No difficulty was experienced in obtaining results with the Gunning-Kjeldahl modification that checked within experimental error. Some trouble, through frothing, will be experienced in the actual digestion, however, where the culture media are high in sugars. This may be overcome by boiling (after adding 15 cc. of concentrated sulphuric acid) slowly for an hour or more, then adding more acid together with 15 gm. of potassium sulphate and 1 gm. of mercury. In our work it became necessary at times to add a third lot of 15 cc. acid—the same amount being always added to both fungus-containing flasks and controls.

Distillation was carried out through block tin tubes which had been in use sufficiently long to obviate the possibility of error through absorption of ammonia—a point observed with new tin by several investigators. The standard acid and alkali were restandardized at short intervals. The same lot of chemicals was always used throughout a single series to insure parallel treatment with both fungus-containing flasks and controls.

Experimental Results and Discussion

The results of our experiments are presented in some detail in table I. It is necessary to note that while the quantities given in column V were obtained by careful weighings, they represent only approximately the quantities present in the solution as determined by analysis (see columns VI and VII). In any series the controls are as nearly perfect as we were able to arrange, that is, the solutions in all the flasks in any one series were taken from a single vessel of the culture medium, the complete mixing of the different constituents in the culture solution being given special attention. In column I the letters A and B given in connection with the series numbers refer to the two nutrient salt solutions employed as de-

scribed on page 424. Where no letters are given there are sufficient indications in column v to identify the culture medium employed. Data for all of the flasks analyzed are included in the table in order that the extent of the experimental error may appear just as well as the average of the determinations made.

TABLE I

NITROGEN FIXATION IN CERTAIN FUNGI AND BACTERIA

I	II	III	IV	V	VI		VII		VIII
Ser. no.	Organism	T. °C.	Per. of gr. days	Sources of N and C supplied, per cent	Total N in flasks containing fungi, mg.		Total N in control flasks, mg.		Diff. = N-fixation
					Comp. data	Average	Comp. data	Average	mg.
1A	*Aspergillus niger*.....	30	30	.7 asparagin 3.6 dextrose	62.510 62.545 63.140	62.732	62.510 62.335 62.300	62.382	.350
2A	*A. niger*.....	30	30	.7 asparagin 1.8 dextrose	61.215 61.985 62.545	61.915	61.915 59.710 61.915	61.180	.735
3A	*A. niger*.....	30	30	.014 asparagin 10.8 dextrose	2.135 1.925 1.820	1.960	2.310 1.995 1.750	2.018	—.058
4A	*A. niger*.....	30	30	.7 asparagin 18.2 dextrose	60.305 59.955 59.990	60.083	60.375 60.585	60.488	—.405
5B	*A. niger*.....	30	30	.014 $(NH_4)_2SO_4$ 3.6 dextrose	1.435 1.575 1.400	1.470	1.470 1.505 1.435	1.470	———
6B	*A. niger*.....	30	30	.7 $(NH_4)_2SO_4$ 18.2 dextrose	70.385 70.420 70.455	70.417	70.490 70.490 70.560	70.547	—.130
7B	*A. niger*.....	30	30	.014 $(NH_4)_2SO_4$ 18.2 dextrose	1.715 1.715	1.715	1.680 1.750 1.715	1.715	———
8B	*Macrosporium commune*.....	25	30	.014 $(NH_4)_2SO_4$ 18.2 dextrose	2.030 2.153	2.091	1.925 2.065 1.995	1.995	.097
9B	*M. commune*	30	7	.7 $(NH_4)_2SO_4$ 18.2 dextrose	70.385 70.420 70.315	70.373	70.420 70.560 70.665	70.548	—.175
10B	*M. commune*	30	7	.014 $(NH_4)_2SO_4$ 18.2 dextrose	1.755 1.890 1.785	1.810	2.065 2.205 1.925	2.065	—.255
11B	*M. commune*	25	30	.0035 $(NH_4)_2SO_4$ 18.2 dextrose	.613 .753 .770	.712	.858 .683 .700	.747	—.035

TABLE I (Continued)

NITROGEN FIXATION IN CERTAIN FUNGI AND BACTERIA

I	II	III	IV	V	VI		VII		VIII
Ser. no.	Organism	T. °C.	Per. of gr. days	Sources of N and C supplied, per cent	Total N in flasks containing fungi, mg.		Total N in control flasks, mg.		Diff. = N-fixation
					Comp. data	Average	Comp. data	Average	mg.
12B	*Penicillium digitatum.*	30	42	.7 $(NH_4)_2SO_4$ 18.2 dextrose	70.455 70.630 70.455	70.513	70.630 70.560 70.665	70.618	—.105
13B	*P. digitatum*	30	42	.014 $(NH_4)_2SO_4$ 18.2 dextrose	2.555 2.590 2.660	2.602	2.660 2.765 2.765	2.730	—.128
14B	*Penicillium expansum*	25	35	.7 $(NH_4)_2SO_4$ 18.2 dextrose	71.890 72.065	71.978	71.540 71.575 71.785	71.633	.345
15B	*P. expansum*	25	35	.014 $(NH_4)_2SO_4$ 18.2 dextrose	2.415 2.345 2.450	2.403	2.415 2.450	2.433	—.030
16	*Glomerella Gossypii*..	25	30	Uschinsky sol. cornmeal decoct.	7.665 7.455 7.770	7.630	7.630 7.875 7.770	7.758	—.128
17B	*Phoma Betae*	25*	25	mangel decoct. 10.0 sucrose	26.635 27.370 26.985	26.997	23.765 23.695	23.730	3.267
18B	*P. Betae*....	25*	25	sugar beet decoct. 10.0 sucrose	16.975 16.870 19.110	17.652	14.665 14.595	14.630	3.022
19B	*P. Betae*....	25*	25	.7 $(NH_4)_2SO_4$ 18.2 dextrose	70.840 70.735 70.525	70.700	68.845 69.020 68.915	68.927	1.773
20B	*P. Betae*.....	25*	25	.014 $(NH_4)_2SO_4$ 18.2 dextrose	2.275 2.030	2.153	2.030 2.415 2.100	2.182	—.029
21B	*P. Betae*....	25*	89	mangel decoct. 10.0 sucrose	53.340 52.570 53.060	52.990	45.220 45.255	45.238	7.752
22B	*P. Betae*....	25*	89	sugar beet decoct. 10.0 sucrose	31.010 31.360	31.185	25.585 25.655	25.620	5.565
23†	*Azotobacter vinelandii*	25	28	soil-compost sol. 5.0 mannite	46.515 46.480 46.445	46.480	5.810 6.405	6.108	40.372
24†	*A. chroococcum*..... (Colorado)	25	28	soil-compost sol. 5.0 mannite	24.570 22.085 22.365	23.007	5.810 6.405	6.108	16.899
25†	*A. chroococcum*..... (Kansas)	25	28	soil-compost sol. 5.0 mannite	22.586 21.735 26.705	23.675	5.810 6.405	6.108	17.567

* 22-25°C.

† In these cases only were 100 cc. of culture solution employed; in all other cases 50 cc.

From our results it is clear that under the conditions of the experiments no fixation can be claimed for *Aspergillus niger, Macrosporium commune, Penicillium digitatum, P. expansum,* and *Glomerella Gossypii.* For the most part, with these fungi, the differences between the various members of any series, including the controls, represent variations which might be expected, and the fact that the averages of the controls are slightly above or below those of the flasks containing the fungi is of little significance.

With *Phoma Betae* the case is different. Here the assimilation of free nitrogen seems definite. The quantities obtained vary from practically 0.0 to 7.75 mg. per 50 cc. of culture medium. All cultures on sugar beet and mangel decoction exhibit a nitrogen increase which points definitely to free nitrogen assimilation. It should be noted that these cultures represent series maintained for a shorter and a longer period of time; those maintained for the longer interval yielding higher fixation quantities than those cultured for the shorter interval. In one series, 19B, where the source of nitrogen is .7 gram $(NH_4)_2SO_4$, the nitrogen difference is perhaps sufficient to indicate nitrogen fixation. At any rate, if we regard fixation as occurring in this solution, it is fair to explain the absence of fixation in series 20B, in which only .014 $(NH_4)_2SO_4$ was employed, as due to the small amount of growth occurring in the last-mentioned series. As would be expected, fixation is somewhat related to the length of the period of growth and to the extent of growth. The results with *Phoma Betae* were so unexpected, in view of the long series of negative values obtained with other fungi, that a further check upon the work was introduced in the following way: A known amount of KNO_3 was added to a series of flasks containing 50 cc. of the sugar beet medium, and analyses were then made to ascertain with what accuracy this nitrogen could be determined. No difficulty was experienced in recovering this nitrate nitrogen, as shown by the data in table II.

Furthermore, it seemed well, as a result of the experiments with *Phoma Betae,* to employ by comparison certain organisms known to have nitrogen-fixing power. Accordingly, the

selected strains of *Azotobacter* were tested, and all yielded positive results of satisfactory magnitude, as shown in table I.

It will be observed in table I that slight discrepancies seem to occur between different series in respect to the amounts of nitrogen recovered—where the different series contained presumably the same amounts of initial nitrogen. This, however, is only an apparent discrepancy, since, as previously

TABLE II

RECOVERY OF NITROGEN AS KNO_3* ADDED TO SUGAR BEET CULTURE MEDIUM

Trials	Controls (no N added) mg.	13.8 mg. N added as KNO_3 mg.	N recovered mg.	Difference mg.
1	14.532	28.227	13.695	—.105
2	14.49	28.048	13.550	—.250

* 13.8 mg. nitrogen as KNO_3 added to 50 cc. sugar beet decoction + 10 per cent cane sugar.

mentioned, this work extended over a considerable period of time, and although the same lot of culture solutions was used for the control flasks and for the flasks in which the organisms were grown in any one series, it was nevertheless necessary to make up new solutions from time to time for the different series. The different series are therefore only approximately comparable.

Now since N-fixation occurs in organisms otherwise so physiologically different as *Azotobacter, Clostridium,* and *Bacillus radicicola,* why may it not occur in all fungi and bacteria, it has been asked time and again. Final answer can be given only in accordance with the results of properly planned and carefully executed experiments. Moreover, it has been shown abundantly that fixation is relatively uncommon among bacteria, the capacity being possessed largely by those groups mentioned above. As has been indicated, among others, Saida, Ternetz, and Stahel have reported fixation for *Aspergillus niger.* In the cases referred to the results are scarcely greater than might occur as experimental errors. This could not apply, however, to the results with *Phoma radicis* and apparently not to those with *Phoma Betae.* Confirmatory evidence

from our own results has certainly designated the Phoma group of organisms as worthy of further careful study.

With respect to the accumulated data for *Penicillium, Macrosporium, Alternaria,* and other saprophytic moulds occurring in the soil or upon decaying vegetation, it can only be said that the data fall into the same category as that for *Aspergillus niger*. We do not take issue with those reporting fixation, but we feel that in view of strong negative evidence regarding many of these fungi, further assurance must be given that the results may not be explained on the ground of experimental errors. We are quite well aware that the admission of the data for *Phoma Betae* has virtually thrown open the whole question for any and all fungi, yet we can find no grounds upon which adequately to criticize either our own results or those of Ternetz with another species of this genus.

Accepting the evidence for certain species of *Phoma,* in what direction shall we seek for organisms similarly endowed? Naturally related genera among the *Sphaeropsidales* would first be suggested, on purely morphological grounds. Again, for a long time physiologists have seen possibilities in organisms which have undergone such adjustment as characterizes the mycorhizal fungi generally. Up to the present time there has existed considerable uncertainty concerning the isolation and determination of the species which produce mycorhiza. Ternetz alone has demonstrated a *Phoma* as a root organism of this type. Peklo's studies lead him to believe that *Penicillium* and an undetermined fungus are involved. In this case, as already noted, a very weak nitrogen fixation was reported. It is not intended, however, in this connection to discuss the various indications respecting mycorhizal fungi. Attention may be drawn to the fact that the predominant presence of *Basidiomycetes* in forests and meadows early suggested the association of these forms with the roots of higher plants. In recent times species of *Tricholoma, Lactarius, Cortinarius,* and *Boletus* have been strongly suspected of being important in the development of mycorhiza.

The fungi are the primary agencies whereby vegetation is usually disintegrated or brought through the first stages of

decay. If it should be positively demonstrated, therefore, that the fungi concerned in this disintegration are at the same time capable of fixing an amount of nitrogen sufficient to prove of practical value, then it would be clear that agricultural practice might be modified in many ways to make greater use of this possibility of nitrogen enrichment accompanying the decay of herbage. As a matter of fact, however, the amount of fixation, as we have seen, reported for *Alternaria, Macrosporium, Cladosporium, Aspergillus, Penicillium,* etc., even by those recent investigators who claim fixation, is very slight—indeed, for such organisms it is usually considerably below 5 mg. per 50 cc. of solution. Assuming that there might be as much fungous felt in 1 cubic foot of ordinary soil as in 100 cc. of a culture[1] and that in both cases the amounts of fixation might be equal, we would have as a maximum 10 mg. nitrogen fixed per cubic foot or 420,000 mg. per acre, 1 foot deep, that is, 420 grams per acre, or about one pound. When it is recalled that in many cultures of *Azotobacter* the fixation has been as high as 50–200 mg. per 100 cc., and when it is further remembered that in the soil the conditions favor quantity of bacterial rather than fungous growth, we may perhaps gain some conception of the impracticability of claiming an economic relation in respect to nitrogen for such fungi.

Summary

1. A review is given of all available literature relating to nitrogen fixation by the fungi.

2. Culture and analytical methods are discussed, and suggestions are made with a view to the elimination of certain possible errors involved in this type of work.

3. Nitrogen fixation could not be demonstrated for *Aspergillus niger, Macrosporium commune, Penicillium digitatum, P. expansum,* and *Glomerella Gossypii.*

4. In cultures of *Phoma Betae* on mangel and on sugar

[1] This seems highly improbable, in the light of recent discussion of this point; compare the following: Conn, H. J. Relative importance of fungi and bacteria in soil. Science N. S. 44: 857–858. 1916.

beet decoction with sugar a nitrogen gain of 3.022–7.752 mg. was established, which seems definitely to indicate fixation.

5. Comparative studies of strains of *Azotobacter* exhibit the usual relatively large fixation of nitrogen in the culture media.

Graduate Laboratory, Missouri Botanical Garden.

Bibliography

Berthelot, M. ('93). Recherches nouvelles sur les microrganismes fixateurs de l'azote. Compt. rend. Acad. Paris **116**: 842–849. 1893.

Brefeld, O. ('00). Versuche über die Stickstoffaufnahme bei den Pflanzen. Schlesischen Ges. f. vaterl. Cultur. Zool.-bot. Sect., Jahresber. **78**: 27–38. 1900.

Chambers, C. O. ('16). The fixation of free nitrogen by certain fungi. Plant World **19**: 175–194. *f. 1.* 1916.

Czapek, F. ('01). Zur Kenntnis der Stickstoffversorgung und Eiweissbildung bei Aspergillus niger. Ber. d. deut. bot. Ges. **19**: p. (139). 1901.

————, ('02). Untersuchungen über die Stickstoffgewinnung und Eiweissbildung der Schimmelpilze. Beitr. z. chem. Physiol. u. Path. **2**: 557–590. 1902. [See p. 559.]

Duggar, B. M., and Knudson, L. ('11). Relation of certain fungi to nitrogen fixation. Science N. S. **33**: 191. 1911.

Fermi, C. ('96). Stickstofffreie Mikroorganismen und Enzyme. Centralbl. f. Bakt. II. **2**: 505–512. 1896.

Frank, B. ('92). Die Assimilation freien Stickstoffs bei den Pflanzen in ihrer Abhängigkeit von Species, von Ernährungsverhältnissen und von Bodenarten. Landw. Jahrb. **21**: 1–44. 1892.

————, ('93). Die Assimilation des freien Stickstoffs durch die Pflanzenwelt. Bot. Zeit. **51**: p. 146. 1893.

Froehlich, H. ('08). Stickstoffbindung durch einige auf abgestorbenen Pflanzen häufige Hyphomyceten. Jahrb. f. wiss. Bot. **45**: 256–302. *f. 1–3.* 1908.

Gerlach, M., und Vogel, I. ('03). Weitere Versuche mit stickstoffbindenden Bakterien. Centralbl. f. Bakt. II. **10**: 636–643. 1903.

Goddard, H. N. ('13). Can fungi living in agricultural soil assimilate free nitrogen? Bot. Gaz. **56**: 249–305. *f. 1–18.* 1913.

Hallier, E. ('67). Gährungserscheinungen. p. 22. Leipzig, 1867. [See also Zeitschr. f. Parasitenkunde **1**: p. 129. 1869.]

Heinze, B. ('06). Sind Pilze imstande, den elementaren Stickstoff der Luft zu verarbeiten und den Boden an Gesamtstickstoff anzureichern? Ann. Myc. **4**: 41–63. 1906. [See pp. 54–55.]

Jodin, M. ('62). Du rôle physiologique de l'azote, faisant suite a un précédent travail présenté à l'Académie dans la séance du 28 avril, 1862. Compt. rend. Acad. Paris **55**: 612–615. 1862.

Koch, A. ('03). Bodenbakterien und Stickstofffrage. Ges. deut. naturforsch. Ärzte, Verhandl. (74 Versamml. zu Karlsbad). **1902**: 182–199. 1903. [See also Koch, in Lafar, Handb. d. tech. Myk. **3**: 1–23. *pl. 1.* 1904–1906.]

Kossowicz, A. ('12). Die Bindung des elementaren Stickstoffs durch Saccharomyceten (Hefen), Monilia candida und Oidium lactis. Zeitschr. f. Gärungsphysiol. **1**: 253–255. 1912.

————, ('14). Zur Frage der Assimilation des elementaren Stickstoffs durch Hefen und Schimmelpilze. Biochem. Zeitschr. **64**: 82–85. 1914.

Latham, M. E. ('09). Nitrogen assimilation of Sterigmatocystis nigra and the effect of chemical stimulation. Torr. Bot. Club, Bul. **36**: 235–244. 1909.

Lindner, P. ('12). Neue Ergebnisse bei Assimilationsversuchen mit verschiedenen Hefen und Pilzen. Chem. Zeit. **36**: 638. 1912. [Abs. in Myc. Centralbl. **2**: 24. 1913.]

Lipman, C. B. ('11–'12). Nitrogen fixation by yeasts and other fungi. Jour. Biol. Chem. **10**: 169–182. 1911–12.

Löhnis, F. ('10). Handbuch der landwirtschaftlichen Bakteriologie. pp. 690–692. Berlin, 1910.

Medisch, M. ('10). Beiträge zur Physiologie der Hypocrea rufa (Pers.). Jahrb. f. wiss. Bot. **48**: 591–631. 1910. [See pp. 625–629.]

Möller, A. ('06). Mykorhizen und Stickstoffernährung. Ber. d. deut. bot. Ges. **24**: 230–234. 1906.

Nägeli, C. W. von ('80). Ernährung der niederen Pilze durch Kohlenstoff- und Stickstoffverbindungen. K. Akad. d. Wiss., München, Sitzungsber. **10**: p. 280. 1880.

Peklo, J. ('13). Neue Beiträge zur Lösung des Mykorrhizaproblems. Zeitschr. f. Gärungsphysiol. **2**: pp. 275–289. 1913.

Pennington, L. H. ('08). Can Fusaria assimilate free nitrogen? Mich. Acad. Sci., Ann. Rept. **10**: 50. 1908.

————, ('11). Upon assimilation of atmospheric nitrogen by fungi. Torr. Bot. Club, Bul. **38**: 135–139. 1911.

Puriewitsch, K. ('95). Ueber die Stickstoffassimilation bei den Schimmelpilzen. Ber. d. deut. bot. Ges. **13**: 342–345. 1895.

Saida, K. ('01). Ueber die Assimilation freien Stickstoffs durch Schimmelpilze. Ber. d. deut. bot. Ges. **19**: (107)–(115). 1901.

Stahel, G. ('11). Stickstoffbindung durch Pilze bei gleichzeitiger Ernährung mit gebundenem Stickstoff. Jahrb. f. wiss. Bot. **49**: 579–615. 1911.

Ternetz, C. ('04). Assimilation des atmosphärischen Stickstoffs durch einen torfbewohnenden Pilz. Ber. d. deut. bot. Ges. **22**: 267–274. 1904.

————, ('07). Über die Assimilation des atmosphärischen Stickstoffes durch Pilze. Jahrb. f. wiss. Bot. **44**: 353–408. *f. 1–6.* 1907.

Traaen, A. E. ('14). Untersuchungen über Bodenpilze aus Norwegen. Nyt Mag. **52**: 19–121. *pl. 4.* 1914. [See pp. 111–113.]

Will, H. ('12). Beiträge zur Kenntnis der Sprosspilze ohne Sporenbildung, welche in Brauereibetrieben und in deren Umgebung vorkommen. Centralbl. f. Bakt. II. **34**: 1–35. 1912. [See pp. 17–22.]

Zikes, H. ('09). Über eine den Luftstickstoff assimilierende Hefe: Torula Wiesneri. K. Akad. d. Wiss., Wien, math.-naturw. Kl., Sitzungsber. **118**: 1091–1133. 1909.

STUDIES IN THE PHYSIOLOGY OF THE FUNGI

II. Lenzites saepiaria Fries, with Special Reference to Enzyme Activity

SANFORD M. ZELLER
Research Fellow in the Henry Shaw School of Botany of Washington University[1]

Introduction

This paper reports the results of an experimental study relating to certain physiological activities of the wood-destroying fungus, *Lenzites saepiaria*. The investigation here reported is concerned primarily with cultural characteristics, some of the factors influencing growth and metabolism, and the enzymic activity in the fungus. Special attention is given to the cyto-hydrolyzing enzymes and the relation of these to the decay produced by *Lenzites*.[2]

The Fungus

This fungus is commonly known by lumbermen as the "brown punk" because of the sepia color of the small bracket-like sporophores. In nature it is generally found on railroad ties, telephone and telegraph poles, and less often on standing timber. It attacks coniferous timber, as a rule, but is known to attack frondose wood (Weir, '14). The sporophores appear near cracks in the wood due to drying. The fruiting surface is made up of branching gills which may become so much

[1] A fellowship established by the Southern Pine Association, New Orleans, La.

[2] In the fall of 1914, in coöperation with the Southern Pine Association of New Orleans, it was decided to attempt a determination of the natural factors of wood influencing in any marked degree the growth and destructive properties of wood-destroying fungi, that is, durability with respect to fungous decay. While the results in this limited field of investigation will be reported in a later paper, the present study deals with those additional physiological phases which were a necessary and fundamental part of the general plan.

While in search for a fungus suitable to employ in such a problem, it was deemed important to make the results as far-reaching in the economic world as possible. Since practically three-fourths of the structural timber used in the United States is furnished by the coniferous species of trees, and since *Lenzites saepiaria* Fries is considered the fungus most destructive to coniferous wood, this fungus was used in the investigation.

anastomosed that the pores formed are very much daedaloid. The mycelium is best studied in pure cultures.

CULTURE RELATIONS

Two methods of securing pure cultures were employed. They may be designated as (1) the tissue method, and (2) the spore method.

(1) The tissue method was first described by Duggar ('05), who applied this method to the making of spawn in mushroom culture. In connection with this study on *Agaricus campestris* tests were made with 69 species of basidiomycetous fungi on various media. Forty of these grew promptly on the media employed. The method was suggested by the fact that "during moist weather, or in a moist cellar where mushrooms are being grown, one will frequently find that an injury in a young mushroom is rapidly healed by a growth of hyphae from the edges of the injured area. The same thing had been noticed in the open in the case of puffballs. In many instances, moreover, pure cultures of fungi in other groups have been obtained by small bits of a sclerotial mass of tissue." Accordingly, young sporophores were obtained, "and after breaking them open longitudinally a number of pieces of tissue from within were carefully removed with a sterile scalpel to a sterile Petri dish." A number of cultures were then made by transferring these nocules of tissue to various forms of nutrient media, such as bean pods, manure, leaf mould, etc. From this and from numerous other similar tests it was ascertained that when the sporophores from which the nocules of tissue were taken were young and healthy, there was seldom an instance in which growth did not result. It was shown that failure to grow was generally due to the advanced age of the sporophore used, to an unfavorable medium, or to bacterial contamination.

In my work dried sporophores were used for the tissue method. These were collected in a freshly growing condition and dried at room temperature. The sporophores of *Lenzites saepiaria* are xerophytic, and will remain viable in a dried condition for some time. Buller ('09, p. 111) found them to

recover after four months of desiccation, while Falck ('09) found that in one case a sporophore was still feebly viable after a year and nine months of desiccation. In my work where the tissue method was employed, the sporophores were broken open, and small pieces of the tissue from the interior were gouged out by means of a sterilized scalpel. These pieces of tissue were quickly flamed and transferred to agar slants in tubes, after dipping in sterile distilled water to moisten. The agar used was Thaxter's glucose-potato-hard agar, made up as commonly employed in this laboratory in the following way: Two hundred grams of potato were cooked for about one hour in a liter of tap water. The potato water strained off was restored to a liter. To this were added 20 grams of glucose and 30 grams of agar, and the mixture autoclaved for 20 minutes to dissolve the agar, which was then tubed, sterilized, and slanted. This is a very good medium for the growth of *Lenzites.*

The tissue transfers grew well, but practically one-half of them were contaminated, since difficulty was found in securing a piece of tissue from the interior of such thin sporophores without contamination.

(2) The spore method was more frequently used in this work. Buller ('09) discovered the remarkable fact that many xerophytic fungi which have been preserved dry for several months or even years may be revived by moistening, when spore expulsion will be resumed and will continue for several days or weeks (according to the specificity of the organism), even after the plants have been dried and revived several times in succession. In the same year, however, Falck reported his work on the desiccation of sporophores of *Lenzites saepiaria, L. abietina,* and *L. thermophila,* in which he used this rejuvenescence due to moisture as an index of viability. The spore method is used considerably in forms with thin tissues, having been employed by Ferguson ('02), Falck ('02), Lyman ('07), Münch ('09), and others.

My procedure differs from those of previous workers in some details, which are given here. To obtain the basidio-

spores the sporophores were rinsed twice in sterile distilled water in large-sized Petri dishes. This removes some of the bacteria and spores of foreign fungi. After this washing process the sporophores were allowed to stand in sterile distilled water for about two hours, so that they were thoroughly saturated. They were removed with sterile forceps and sponged off with Scott's tissue toweling which had been previously sterilized, and were then placed, hymenium downward, in large, dry, sterile Petri dishes. After 24–48 hours the sporophores had discharged enough spores to make a white spore print. The moisture in the sporophores serves two purposes other than reviving the tissues. It keeps the air in the dish sufficiently humid to prevent too rapid desiccation, and it also tends to hold foreign spores to the surface of the sporophores. The latter is beneficial in securing a fairly pure dispersion of spores.

The spore dispersion was made in sterile distilled water. Test-tube water-blanks were prepared and sterilized. Several loopfuls of sterile water were transferred to the spore print by means of a platinum loop. By stirring a little with the loop the spores were so dispersed that when a loopful of the spore suspension was transferred to the water-blank a cloudy streak was produced. Three or four such loopfuls of the spore suspension were transferred to a water-blank, which was well shaken by rolling between the palms of the hands. Two or three loopfuls were transferred to each of several tubes of melted agar, and poured plates were made as in the usual bacteriological method. Plates made in this way with the 3 per cent agar mentioned above were surprisingly free from bacterial contamination but contained a few scattering colonies of foreign moulds. The colonies produced by the germinating spores of *Lenzites* were so characteristic, however, and so generally scattered over the plates that they soon became easily recognizable. Individual colonies from the plates were transferred to agar slants, a quantity of cultures being obtained.

CHARACTERISTICS OF THE MYCELIUM IN CULTURE

Lenzites saepiaria was kept in cultures on three types of media, i.e., Thaxter's glucose-potato-hard agar described above, yellow pine sawdust in Erlenmeyer flasks, and pine blocks in jars and bottles. The mycelial characters on wood are somewhat different from those on agar.

Polymorphism.—Polymorphism in the *Basidiomycetes* has been reported by many early investigators, and in late years especially by Falck in 1902 and Lyman in 1907. Lyman reviews the literature dealing with the occurrence of oidia, chlamydospores, and conidia in certain *Polyporaceae,* and in his own work finds that many of the *Hymenomycetes* possess these several ways of reproducing vegetatively. In 1909 Falck published a monograph on *Lenzites* in which he describes minutely the morphology and physiology of the mycelium of *L. saepiaria.* The polymorphism of this fungus is extremely interesting and characteristic, the pure cultures of the mycelium being almost sufficient to identify the fungus.

The mycelium is white at first, but with age the aërial part becomes a reddish brown or sepia color. When the mycelium grows out from an inoculum on agar, there is a submersed mycelium which is a forerunner of the superficial. From the latter there arises a woven mat of aërial hyphae which take on the sepia color with age. The hyphae are very much septate, and clamp connections are quite common. These vary from the ordinary clamp connections through all stages to the medallion mycelium, as Falck calls it, which is found only in the wood and sawdust cultures.

Falck divides the oidia into primary, secondary, and tertiary. The primary oidia are those formed when the whole superficial mycelium breaks up into chains of spore-like cells. The secondary are those produced at the tips of branches of the superficial mycelium. These may be abnormally swollen tips or very short chains from lateral branches. The tertiary oidia are the most common and appear on the aërial hyphae. The hyphae generally break at clamp connections to produce this type. The chlamydospores or gemmae are nothing more than swollen vegetative cells of the hyphae, which

act as conidia when isolated. In the superficial mycelium they are larger than where submersed in agar, and are often found in the medallion mycelium in the decayed wood.

In the cultures on blocks of pine wood the mycelium spreads well if the blocks are fairly well saturated with water. As the moisture disappears the mycelium usually penetrates, and the superficial mycelium dries and vanishes. In this later stage of growth, however, it is difficult to see whether the blocks are well infected or whether the fungus has failed to enter and thus has dried down. In the woody tissues the hyphae extend lengthwise of the tracheids as a general rule. The medullary rays are usually full of matted hyphae. When passing from one tracheid to another the hyphae penetrate the pits. Very infrequently, however, they penetrate the walls of the spring wood, and in such cases are constricted in the tiny perforation, but are swollen, forming a callus on either side of the wall. When two active hyphae come together laterally they fuse, and the whole often forms an anastomosing network. The medallions are extremely common.

CHARACTERISTICS OF THE SPOROPHORES IN CULTURE

Well-differentiated sporophores were formed on sawdust and pine blocks, and in a few cases sporophores occurred on agar. The earliest fruiting bodies appeared about seven months after the cultures were inoculated, and were thelephoroid or staghorn-like in shape. The flattened projections bear the hymenium on both sides. It is composed of clavate paraphyses with the typical four-spored basidia. Still better-differentiated sporophores were produced in from eleven to twelve months, their form depending upon the surface of the substrate. On a horizontal surface they are almost sessile and hemispherical, with the upper surface composed of tiny daedaloid pores, while the under surface has the typical lamellate hymenium of *Lenzites*. When fruit bodies appear on the side of a block they tend toward the bracket form, but have hymenium above and below, the upper poroid, the lower lamellate or hydnoid. Plate 8 shows sporophores both on sawdust and on pine block cultures.

Increase in sporophore-producing capacity.—The basidiospores from one of the sporophores produced in pure cultures were caught in a sterile Petri dish and plated out in agar as described above. There was a large per cent of germination. The pure culture tubes made from these germinated spores produced sporophores on agar in eight weeks after the transfers were made. This is the only instance where I secured sporophores of *Lenzites saepiaria* on agar. It seems plausible to conclude that by growing the fungus in pure cultures the ability to produce sporophores in cultures is increased in the following generation.

FACTORS INFLUENCING THE GROWTH AND METABOLISM OF THE FUNGUS

In this connection four different factors are discussed. These are (1) the relation to the reaction of media, (2) temperature relations, (3) the water and oxygen content of the substrate, and (4) resin on wounds and in the wood.

(1) The relation to the reaction of media, with special reference to chemical composition, i. e., source of carbon and other nutrients for best germination and growth, has been amply considered by Rumbold ('08), and by Falck ('09) in his monograph on the Lenzites rots. Thus it was not considered necessary to dwell upon these factors further than is reported elsewhere in this paper. However, in making a new supply of cultures of *Lenzites saepiaria, Fomes pinicola, Polystictus hirsutus, Polyporus lucidus* and others, I found that after transferring to the new medium the fungi would not grow. On testing with litmus this medium proved to be slightly alkaline. A readjustment of the reaction to slight acidity yielded a suitable medium for these forms. Rumbold ('08) also found that *L. saepiaria* is very sensitive to alkaline media, and Spaulding ('11, p. 19) found that "a number of experiments uniformly gave the same results with this species. It was found that even with one-fourth of one per cent of sulphuric acid it grew luxuriantly."

(2) In Falck's ('09) paper temperature relations are discussed at length. He shows that *L. saepiaria* has a growth

range from a minimum of 5°C. to a maximum of 44°C., with 35°C. as an optimum temperature. This optimum holds for the strain of this species that I used, but the total range of temperature was not determined. A question still remains whether the optimum temperature for growth is an optimum for the complex of enzyme activities which take place during decay. With this in mind the cultures were maintained at 25–30°C., since these temperatures are at least conducive to growth, and enzyme action *in vitro* is rapid within these limits.

(3) Given some specific wood as a suitable substrate and a favorable temperature, then the growth of *L. saepiaria* will be related to such other factors as porosity, water content, oxygen tension, and abundance of stored starches or other food materials in the wood. The oxygen content of wood is necessarily related inversely to water content, provided there is water in excess of that imbibed by the tracheid walls. Variation in the imbibed water must influence the degree of humidity of the air in the lumen of the tracheids, and doubtless the humidity of this enclosed air plays a rôle in the growth of the fungus through the wood. Another factor which influences the oxygen content of wood is the average size of the cell lumen. This decreases in size from the spring to the late summer wood, for in the latter the lignification increases the thickness of the walls at the expense of lumen capacity. High specific weight is directly related to the amount of summer growth (Johnson, '93). This necessarily means that as the specific weight of the wood increases the oxygen content would be decreased.

Münch ('09) has shown by numerous experiments with various forms of wood-destroying fungi that air content is an important factor influencing the entrance of fungi. The greater number of the forms which he used have a high air requirement. The quantity of wood fibre is also important. He mentions the fact that narrow annual rings are more resistant than broad ones, because there is less capacity for air in the narrower. In specimens of wood where only some rings are decayed the decayed rings prove to be the more

porous ones. This shows that a certain undetermined minimum of oxygen will prevent the growth of certain fungi. Exceptions to this, however, may be numerous. For instance, Münch found that *Armillaria mellea* is not dependent on air in the substrate. The rhizomorphs of this organism are of such a structure that they conduct air into water-saturated tissues. Doubtless there are other forms which have the power to thus conduct air to parts where there is a paucity of air.

Undoubtedly, high water content will inhibit the entrance of certain fungi, but as soon as there is a paucity of water the tissues are as susceptible as ever, for there is no change in the properties of the host tissues themselves. Thus, an increased water content as a factor in the immunization of a host plant against disease (as Münch would lead one to think) is not compatible with present-day ideas of immunity.

Appel ('15) concurs in Münch's idea that the paucity of air due to high water content may be made an effective method in the control of certain plant diseases. He applies this to die-back diseases of trees due to species of *Valsa* and other fungi. He says:

> "When such diseases occur, you will find the cause in defective irrigation methods, which may be remedied by changing the irrigation system. It is of the greatest importance that the land be irrigated at the time the trees contain less water and plenty of air, and that the next irrigations be made in time to prevent an excessive decrease of the water in the tissues."

Further, he states that the same principle may be found to be applicable to bacterial diseases of trees, especially *Bacillus amylovorus,* and finally remarks:

> "It may be possible that not only trees, but also herbaceous plants, show relations between fungous growth and air content. I think it must be so for the organisms which cause the wilt diseases and the rhizoctonia disease of the potato, both of which have a high air requirement. . . . . Though caused by a fungus, the production of conditions favorable to the progress of the disease [*Rhizoctonia*] is attributable to irrigation."

The writer believes that the close application of the work of Münch given by Appel to such diseases as those caused by

Bacillus amylovorus and *Rhizoctonia* is hardly acceptable without adequate specific data for each of the organisms concerned.

Speaking of the fungous diseases in the tropics, Westerdijk ('15) says:

> "The heavy rainfalls, combined with the abundant transpiration—owing to the intense heat, must cause a high water-content and a small air-content, of the wood-vessels of the trees, thereby making a substratum poor in air. This fact, combined with the high temperature, would explain the rare occurrence of *Hymenomycetae* and other wood-destroying fungi in the tropics."

A certain balance between water and oxygen is necessary, and this varies according to the specificity of the organism. Just what percentage of water in the cell walls and oxygen in the lumen of the wood fibres are necessary for the entrance of fungi are undetermined factors, but we know that both are necessary. Well-seasoned wood is very durable as long as it is kept dry. On the other hand, upon damp wood spores of fungi germinate and penetrate readily. In speaking of *Lenzites spp.* Falck ('09, p. 223) says that the spores germinate with every rain, then there forms a small colony from which hyphae enter the wood substance. In such colonies are found the typical medallion mycelium which endures dry periods, and which after a thorough saturation with water is again able to continue its life activities undisturbed.

Wehmer ('14) found that bits of mycelium of *Merulius lacrymans* transferred to air-dried blocks would not grow at room or cellar humidity. When the blocks were well saturated with water better results were obtained for mycelial growth, but decay was not evident in all cases. As decay by *Merulius* spreads the moisture content increases, decayed wood showing 25 per cent hygroscopic water in damp air, where sound pine holds but 15 per cent.

During the course of my work with *Lenzites* grown on pine blocks some interesting facts were noted concerning the growth and decay as they were influenced by the water and oxygen content of the wood. Blocks which were sterilized

without excess of water were inoculated and enough water added from time to time to keep the humidity high, but the mycelium did not spread far from the place of inoculation. Where the blocks were kept saturated until after inoculation the mycelium grew rapidly over the surface, no matter what the nature of the block. As the water evaporates the mycelium penetrates, and the superficial growth dries down and disappears. The interior of the blocks, however, holds moisture for a longer time than the surface, and in such a proportion to the wood fibre that the nearest to optimal water content is reserved in the interior. This is shown by examples of Lenzites rot wherever it is found in nature, as well as in pure cultures. Blocks that show a reduction in weight (due to decay) of from 40–60 per cent show internal decay, with a crust of fairly sound wood over the surface. If two blocks fit rather closely together during incubation the surfaces in contact may be decayed.

A large series of blocks inoculated with *L. saepiaria* were kept saturated for a year, and they were reduced very little by the fungus. The reduction was all superficial and appeared as a "scorching" of the surface. Microscopic examination showed that the hyphae penetrated to a depth of but three or four tracheids. Plate 8, figs. 13–17, shows a series of blocks having this superficial "scorching," and figs. 8–12 show the internal decay mentioned above. From these observations it is apparent that the oxygen requirement of *L. saepiaria* is low. A certain percentage of water is a necessary factor, but total saturation is injurious to the fungus because of the paucity of oxygen. The optimum, maximum, and minimum percentages of air and water have not been determined.

From the above observations it will be seen that any factors influencing the proportion of water and air are of great importance. Seasonal cracks, due to drying, of ties and other structural timbers afford an entrance place for the fungus and the necessary air, and usually the decay is found in radial blotches when the end of an infected timber is observed.

(4) When coniferous trees are wounded in one way or another the majority of them exude pure resin from the

bark, and this seals the wounds to the exclusion of the fungus. We have found that the mycelium of *L. saepiaria* will not grow on 100 per cent resin plates because of the lack of nutrition, nor will the spores germinate on such a medium. In living trees, then, the pure resin covering the wounds serves a twofold purpose. It mechanically prevents the entrance of the fungus, and excludes the air which might otherwise gain access to the interior of the tree more rapidly than under natural conditions. Resin does not exist in this high percentage, however, in the interior of wood, but is infiltrated into the lignified walls. Hence, there is still air in the lumen and food accessible to the fungus. Laboratory experiments reported below have shown that under these conditions the presence of resin has very little influence upon the growth of the fungus, at least up to 50 per cent resin by weight, which is considerably more than is found in any coniferous wood.

A quantity of resin was extracted by means of benzol from longleaf pine wood (*Pinus palustris*). The resin was hardened at 65°C. until it was of a constant weight. This was used in making a resin agar, the basis of which was a 4 per cent Thaxter's glucose-potato-hard agar. The powdered resin was added to the agar while warm, emulsified by vigorous agitation, and then sterilized. Sterilization may be done in the Arnold sterilizer on three successive days, or if it is necessary to sterilize but once, autoclaving is satisfactory; but when autoclaved more than once the resin seems to be acid enough to hydrolyze the agar sufficiently to keep it from hardening. If the agar is removed from the autoclave while it is still quite super-heated and vigorously agitated while it is cooled by placing under the water tap from time to time, a very satisfactory emulsion of any percentage may be obtained.

The agar was made up so as to contain 5, 10, 15, 20, etc., up to 100 per cent, of resin, which was plated out and after cooling was inoculated with squares of mycelium of *L. saepiaria* cut as suggested by Humphrey and Fleming ('15, pl. 1). The inocula were 0.8 cm. on a side. After 14 days of growth at 32°C. measurements of the diameters of the grow-

ing mycelial colonies were taken. Plate 9 shows photographs of the comparative growths. The accompanying table (table 1) shows that on the 5 per cent resin agar the growth was reduced somewhat, as compared with the control containing no resin; but the growth was just about as rapid on 40, 45, and

TABLE I

RESULTS OF GROWING LENZITES SAEPIARIA ON PLATES OF RESIN AGAR

Per cent of resin	Diameter of growth on resin agar plates after 14 days at 32°C.				
	Plate no. 1	Plate no. 2	Plate no. 3	Plate no. 4	Averages
	cm.	cm.	cm.	cm.	cm.
0 (control)	9.0	9.0	9.0	9.0	9.0*
5	7.6	7.4	6.8	7.9	7.42
10	6.1	6.2	6.7	7.4	6.6
15	6.8	6.5	7.2	5.5	6.5
20	6.2	6.1	5.9	6.2	6.1
25	6.4	6.8	6.9	6.4	6.63
30	6.2	5.7	6.2	5.9	6.0
35	6.8	7.0	6.6	6.8	6.8
40	6.5	6.2	6.6	6.4	6.4
45	7.4	7.0	6.6	6.4	6.85
50	5.9	6.2	5.7	6.0	5.95
55	3.4	3.5	3.8	3.7	3.6
60	1.3	1.5	1.8	1.4	1.5
65	1.8	1.4	1.7	1.5	1.6
70	1.8	1.6	1.7	1.3	1.6
75	1.6	1.7	1.8	1.7	1.7
80	1.4	1.5	1.1	1.2	1.3
85	1.5	1.6	1.4	1.4	1.5
90	0.8	0.8	0.9	1.1	0.9
95	0.8	0.8	0.8	1.2	0.9
100	0.8	0.8	0.8	0.8	0.8

* The diameter of the inoculum in each case was 0.8 cm., which should be subtracted from the above values in order to obtain the actual growth.

50 per cent resin as on 5, 10, and 15 per cent, the average growth of the former three being 6.4 cm., and of the latter 6.84 cm. From 50 to 60 per cent there was an abrupt change in the growth, which showed marked inhibition from 60 to 85 per cent, while above this there was practically no growth. The fact that there was some growth up to 85 per cent resin is conclusive evidence that resin is not toxic. Of course, it could not be toxic unless soluble in water or the enzymic fluids excreted by the fungus. Its greatest inhibitive power lies in the fact that it excludes water from the substrate. The results given

here are merely indicative of the true conditions as they exist in nature, since the nutrition in the two cases is different. We know from the work done by Le Renard ('12) that the composition of the nutrient medium used in such Petri dish plates has a marked influence on the effect of any toxic substance present; that is, if the nutritive elements present are varied in quantity there is a change in the effect of the toxic substance on the growth of the organism.

Resin determinations have been made on approximately 450 series of pine blocks, the whole comprising about 3000 samples which were placed in cultures of *L. saepiaria*. The reduction in weight of these blocks, after incubation for one year, varies considerably, but the results so far taken tend to show that the influence of resin on the decay by this fungus is exceedingly erratic. This will be reported in a second paper.

Enzyme Activity in Lenzites saepiaria

Work on the enzyme activity of the wood-destroying fungi is comparatively meagre. This is especially the status of the cytolytic investigations. There are very few papers wholly devoted to enzymes of higher fungi. In 1895 Bourquelot and Hérissey investigated the enzymes from the juice of the sporophores of *Polyporus sulphureus*. The enzymes were precipitated with alcohol. Czapek, in 1899, found in natural infections of *Merulius lacrymans* an active principle capable of liberating from lignin the substance which gives the lignin reactions in alcoholic extracts. This substance, which is discussed more fully later in this paper, he called "hadromal," and the enzyme capable of liberating it was called "hadromase."

Two years later Kohnstamm ('01) applied Buchner's "Dauerhefe" method to the sporophores and mycelium of *Merulius lacrymans* and *Armillaria mellea*. He obtained evidence of the presence in these fungi of diastatic, proteolytic, glucoside-splitting, and cellulose-hydrolyzing enzymes. Buller ('06) tested out the juice expressed from the sporophores of *Polyporus squamosus* and obtained positive evidence of the

presence of eight enzymes. Reed ('13) grew *Glomerella rufomaculans* in cultures of nutrient solutions, and from the dried fungous mat was prepared a fine, enzyme-containing meal which was tested on various substrates.

The few papers mentioned are the main ones dealing entirely with enzyme activity in fungi which attack wood. Many other investigators have inferred *a priori* that many enzymes, especially cytolytic, are active agents in the metabolism of this group of fungi, and scattering references of this sort are numerous. It is of interest to observe that although we have every indication to direct us to believe that cytases are present in wood-destroying fungi, yet their presence has been demonstrated only indirectly, i.e., by histological methods. This may be due to the fact, as will be pointed out later, that a majority of the investigators who found no wood-destroying ferment used the fruiting bodies in their experiments instead of the active, vegetative mycelium. More detailed discussions of the results of these various investigators will be given below in connection with the various groups of enzymes considered in this paper.

In view of the status of our knowledge of the enzymes concerned in the destruction of wood, I undertook an investigation to compare in a qualitative way the enzymes of the mycelium and sporophores of *Lenzites saepiaria*. In certain cases only have quantitative results been obtained.

METHOD OF GROWING MYCELIUM FOR EXTRACTION

Sawdust of *Pinus palustris, P. echinata,* and *P. Taeda* was placed in flasks of 1000 and 500 cc. capacity. The sawdust was moistened with distilled water, after which the flasks were plugged and sterilized in the autoclave at 20 pounds pressure for 45 minutes. After cooling, the sawdust was inoculated with the mycelium from agar slants. As the mycelium grew into the sawdust there was a darkening of the wood similar to that noticed in the "rot" produced in nature by this fungus. In the course of time the sawdust became a dark brown color.

After about 7 months some of the flasks were emptied, and the sawdust with the mycelium was dried by means of an

electric fan blowing a draft of warm air (about 30°C.) over it. After being dried the sawdust could be crushed to powder between the fingers. This dry sawdust was ground to a very fine powder in an ordinary mill. A tared amount of the powder was transferred to a clean liter flask, and about 4 parts of water by volume were added with about 1 per cent chloroform. This was allowed to stand for 16 hours for the extraction of enzymes. Then the solution was filtered off through a Buchner funnel, and the enzymes precipitated from the filtrate by the addition of 3 volumes of 95 per cent alcohol. The precipitate was collected on a filter paper in a Buchner funnel, and the paper allowed to dry at room temperature. These filter papers were kept in glass-stoppered bottles for future use.

When the enzyme preparation was to be used the filter paper was soaked in such a quantity of water that each cubic centimeter of the resulting enzyme "dispersion" was equivalent to 1.5 grams of the original sawdust powder. In the following work 2 cc. of this dispersion were used in 10 cc. of the respective substrates.

PREPARATION OF SOROPHORES FOR EXTRACTION

Sporophores of *Lenzites saepiaria* were collected by the writer at Leeper, Missouri. Only the viable, light sepia-colored specimens were used in the enzyme work. The tissue of the sporophores, after grinding, was treated in the same way as described above for the mycelium in sawdust. The enzyme preparation was secured in the same way, and 1 cc. of the enzyme dispersion in water had the value of 1.5 grams of the original sporophoral meal. Unless otherwise specified in the following pages "mycelial meal" will refer to the original powdered sawdust including mycelium before extraction, "sporophoral meal," the original ground sporophores before extraction, "mycelial dispersion," the dispersion of enzymes extracted from the mycelial meal, and "sporophoral dispersion," the dispersion of enzymes extracted from the sporophoral meal.

ENZYMES OF LENZITES SAEPIARIA

ESTERASES

By the action of esterases the esters of the fatty acids are saponified and are thus resolved into their constituents, alcohols and fatty acids. It is thus possible to recognize and measure the activity of the enzymes in decomposing esters by determining the acidity of the substrate quantitatively by titration against alkali.

The presence of fatty globules in the hyphae of fungi has led to the investigation of the enzymes capable of accomplishing their hydrolysis. Biffen ('99) found a fat-destroying fungus belonging to the *Hypocreales* which grew luxuriantly on the endosperm and milk of the cocoanut. All cultures of the fungus showed that the fats became emulsified, and the substrate became increasingly acid with continued growth and had a pleasant ethereal odor something like that of amyl butyrate. On triturating the mycelium with kieselguhr, and filtering under pressure, he obtained an extract which decomposed both cocoanut oil and monobutyrin. Buller ('06) found that 10 cc. of the juice from the sporophores of *Polyporus squamosus* hydrolyzed 43 per cent of a 1.84 per cent ethyl acetate solution in 330 hours. He mentions "that when spores of *Polyporus squamosus* are allowed to dry for several days, many of them develop large fat drops. On germination of the spores in malt-wort extract these drops disappear. Perhaps this is due to the action of lipase." Bayliss ('08) was not able to demonstrate the presence of lipase in *Polystictus versicolor*. Dox ('10) has reviewed the literature concerning the filamentous fungi which split the fats. Reed ('13) found that the enzyme powder prepared from *Glomerella rufomaculans* split ethyl acetate and ethyl butyrate, but that the increase in acidity was much greater where ethyl acetate was used as the substrate.

The presence of oil globules in the spores and mycelium of *L. saepiaria* led to the investigation of the power of the fungus to utilize such substances. Thus, experiments were conducted using as substrates the following: olive oil emul-

sion, triacetin, methyl acetate, ethyl acetate, and ethyl butyrate.

Olive oil emulsion was made according to Bloor's ('14) method, which was previously reported from this laboratory by Davis ('15). Ten cubic centimeters of olive oil were dissolved in hot, absolute alcohol. This was run through a hot funnel to which was attached a piece of glass tubing drawn out to a very fine jet. The fine stream of oil in alcohol was run into 100 cc. of cold distilled water, which was constantly stirred. The milk-white emulsion was finally boiled to drive off the alcohol, then was diluted to 500 cc. with distilled water.

The other substrates were made up in 1 per cent solutions, and if kept any length of time toluol was added as an antiseptic. All substrates were used according to the following example and were always set up in duplicate:

(1) 25 cc. ethyl acetate + 5 cc. enzyme dispersion + toluol.

(2) 25 cc. ethyl acetate + 5 cc. enzyme dispersion (autoclaved) + toluol.

(3) 25 cc. ethyl acetate + 5 cc. water + toluol.

(4) 25 cc. ethyl acetate + equivalent weight meal + toluol.

(5) 25 cc. ethyl acetate + equivalent weight meal (autoclaved) + toluol.

The results show that the lipolytic action on neutral fats is very slight, if any, but that on the esters of the lower fatty acids it is more marked. As Reed ('13) observed for *Glomerella rufomaculans,* here the acetates are better substrates than the butyrates. Methyl acetate is more strongly hydrolyzed than ethyl acetate.

Table II shows the results of the action of the esterases in the mycelial meal and the enzyme dispersion from the mycelium. These cultures were incubated for 24 days at a temperature of 25–30°C. Table III shows the lipolytic action in the sporophores under the same conditions. Since the mycelial meal includes the sawdust upon which the mycelium grew, the results obtained for the mycelium and sporophores are not comparable, but from the results on methyl acetate it can be readily seen that the esterase activity in the mycelium is stronger than in the sporophores.

TABLE II

ACTION OF ESTERASES OF THE MYCELIUM UPON VARIOUS SUBSTRATES

Substrate	Form of enzyme material	Number cc. N/20 NaOH to neutralize 10 cc. substrate	
		Gross	Net
Methyl acetate...	Enzyme dispersion.....	2.95	2.30
Methyl acetate...	Enzyme dispersion (autoclaved)..	0.65	.....
Ethyl acetate.....	Enzyme dispersion.....	1.60	0.70
Ethyl acetate.....	Enzyme dispersion (autoclaved)..	0.90	.....
Ethyl butyrate ...	Enzyme dispersion.....	0.15	0.05
Ethyl butyrate ...	Enzyme dispersion (autoclaved)..	0.10	.....
Olive oil emulsion..	Enzyme dispersion.....	0.35	0.10
Olive oil emulsion..	Enzyme dispersion (autoclaved)..	0.25	.....
Olive oil emulsion..	Equivalent weight of meal.....	7.57	0.07
Olive oil emulsion..	Equivalent weight of meal (autoclaved).....	7.50	.....
Triacetin.....	Equivalent weight of meal.....	9.08	0.48
Triacetin.....	Equivalent weight of meal (autoclaved).....	8.60	.....

TABLE III

ACTION OF ESTERASES OF THE SPOROPHORES UPON VARIOUS SUBSTRATES

Substrate	Form of enzyme material	Number cc. N/20 NaOH to neutralize 10 cc. substrate	
		Gross	Net
Methyl acetate...	Enzyme dispersion.....	7.10	2.30
Methyl acetate...	Enzyme dispersion (autoclaved)..	4.80	.....
Methyl acetate...	Equivalent wt. meal.....	12.30	5.90
Methyl acetate...	Equivalent wt. meal (autoclaved)	6.40	.....
Ethyl acetate.....	Enzyme dispersion.....	4.55	1.25
Ethyl acetate.....	Enzyme dispersion (autoclaved)..	3.10	.....
Ethyl acetate.....	Equivalent wt. meal.....	9.40	4.70
Ethyl acetate.....	Equivalent wt. meal (autoclaved)	4.70	.....
Ethyl butyrate....	Enzyme dispersion.....	0.42	0.07
Ethyl butyrate....	Enzyme dispersion (autoclaved)..	0.35	.....
Ethyl butyrate....	Equivalent wt. meal.....	2.65	0.95
Ethyl butyrate....	Equivalent wt. meal (autoclaved)	1.70	.....
Olive oil emulsion..	Enzyme dispersion.....	1.10	0.25
Olive oil emulsion..	Enzyme dispersion (autoclaved)..	0.85	.....

MALTASE

Of the disaccharases, I tested for maltase, lactase, and invertase. The occurrence of maltase in some of the lower fungi is of special interest and importance, but the literature has been adequately discussed by Dox ('10). In the higher fungi it has been demonstrated in the sporophores of *Polyp-*

orus sulphureus by Bourquelot and Hérissey ('95), and by the writer it has been found both in the mycelium and sporophores of *L. saepiaria.*

In our experimental work a 1 per cent solution of maltose was used as a substrate. Ten cubic centimeters of this were placed in each of 6 test-tubes. To each of 2 of these were added 2 cc. of the mycelial dispersion, to each of 2 others,

TABLE IV

SHOWING THE ACTION OF MALTASE IN LENZITES SAEPIARIA AFTER TWO WEEKS AT 25–30°C.

Amount of enzyme dispersion in 10 cc. of 1 per cent maltose	Reducing sugars as glucose in 5 cc. of substrate		Net due to hydrolysis by maltase	
	Mycelium	Sporophore	Mycelium	Sporophore
	mg.	mg.	mg.	mg.
2 cc.	40.40	39.24	6.28	18.61
2 cc. (autoclaved)	34.12	20.63	.....	.....
2 cc. dist. water	26.16	19.72	.....	.....

2 cc. of the mycelial dispersion which had been autoclaved to kill the enzymes, and to each of the remaining were added 2 cc. of distilled water. To all were added a few drops of toluol as an antiseptic. A comparable series of experiments was set up using sporophoral dispersion. All were incubated at 25–30°C. for 2 weeks, after which time they were tested for reducing sugars by Shaffer's method ('14). Maltase reduces Fehling's solution, but when it is hydrolyzed each molecule yields 2 of glucose which would reduce almost twice as much Fehling's solution. Table IV shows that there was considerably more reduction in the "regular" tubes than in the autoclaved and the water controls. The fact that there is more net reduction due to maltase in the sporophores than in the mycelium is not of any significance when the amount of sawdust in the mycelial powder is considered.

LACTASE

Lactase has never been reported from the higher fungi. In dealing with lactase the same procedure was carried out

as for maltase, except that a 1 per cent solution of lactose was used for a substrate. There was no indication of the presence of lactase either in the mycelium or the sporophores.

INVERTASE

Although invertase has been repeatedly demonstrated in lower fungi, especially yeasts, *Aspergillus* and *Penicillium,* its presence has seldom been noted in the higher forms. Bayliss ('08) found it in the sporophores of *Polystictus versicolor,* and it is undoubtedly present both in the mycelium and sporophores of *L. saepiaria.*

To demonstrate the presence of invertase a 1 per cent solution of sucrose was used as a substrate. To 10-cc. portions of this were added 2 cc. of the enzyme dispersions, enzyme dispersions autoclaved, and 2 cc. of distilled water, as in the maltase experiments. After 4 hours there was distinct reduction of copper oxide from Fehling's solution in the regular tubes, but the autoclaved controls and the water controls showed none. This was perhaps more evident in the sporophoral dispersion.

Having demonstrated the presence of invertase both in the mycelium and sporophores, some quantitative studies were made. The fungus was successfully grown upon a substrate of carrot juice. The carrot juice cultures were made in Erlenmeyer flasks and inoculated with oidia from cultures grown on pine sawdust. The oidia were dispersed in sterile, distilled water-blanks from which the inoculations were made. After 2 weeks of growth the mats of mycelium were removed from the flasks and dried on filter paper at a temperature of about 35°C. This dried mycelium was ground to a fine powder in a mill and kept dry in a glass-stoppered bottle. This same powder was used for quantitative determinations of diastatic action reported later in this paper.

The experiments were conducted as follows: To 50 cc. of a 1 per cent sucrose solution 2 grams of fungous powder were added, with about 1 per cent toluol as an antiseptic. As a control on this, other experiments were prepared in the same way after the fungous powder had been autoclaved to kill the

enzyme. The sucrose solution was also used alone. These were all set up in duplicate, and at the same time parallel experiments were set up with sporophoral meal in the same way. They were allowed to remain at room temperature (about 27°C.). After a period of 3 hours one set of cultures was killed in the autoclave by allowing the pressure to come to 10 pounds. The duplicate set remained in incubation for

TABLE V

QUANTITATIVE STUDY OF THE INVERTASE ACTIVITY IN MYCELIUM AND SPOROPHORES

Amount of fungous powder in 50 cc. of 1 per cent sucrose solution	Reducing sugars as glucose in 10 cc. of substrate				Net invert sugar due to invertase activity			
	After 3 hrs. incubation		After 6 hrs. incubation		After 3 hrs. incubation		After 6 hrs. incubation	
	Mycelium	Sporophore	Mycelium	Sporophore	Mycelium	Sporophore	Mycelium	Sporophore
	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.
2 grams	7.52	2.88	17.19	5.16	5.44	2.25	15.05	4.53
2 grams (autoclaved)	2.08	0.63	2.14	0.63	.....	.....	.....	.....
Sucrose solution alone	Negligible	.....	Negligible	.....	.....	.....	.....	.....

6 hours and then was killed in the same way. After killing the substrates were filtered, and the invert sugars were determined by the Shaffer method. Table v gives these quantitative results. These results show definitely that the greater invertase activity is in the vegetative part of the fungus, the inversion taking place over twice as rapidly in the mycelium as in the sporophores. In collecting such sessile sporophores as those of *L. saepiaria* it is difficult at times to remove the fruiting body without taking with it some superficial mycelium. It may be that if only the marginal portions of the sporophores were used in this work there would be a greater difference in the activity between fruiting body and mycelium.

RAFFINASE

A carbohydrase which transforms the trisaccharide raffinose into fructose and melibiose was demonstrated. To 10

cc. of a 1 per cent solution of raffinose were added 2 cc. of enzyme dispersion and toluol as an antiseptic. Controls were prepared as in previous experiments. After 48 hours Fehling's solution was strongly reduced in all but the controls. This was true both for the enzyme preparations from the mycelium and the sporophores. This gives evidence of the presence of raffinase in *L. saepiaria.*

Dox ('10) has reviewed the literature as to the occurrence of this ferment in *Aspergillus* and *Penicillium.* He found that mould powder of *Penicillium Camemberti* hydrolyzed raffinose, and that varying the source of carbon in the substrate exerted an influence on the amount of raffinase produced. A significant fact brought out is that lactose and sucrose yielded a larger quantity of raffinase than did other carbohydrates, and these two disaccharides, it is to be noted, contain two of the hexoses found in raffinose; that is, lactose on hydrolysis yields galactose and dextrose, and sucrose yields dextrose and levulose.

The presence of raffinase in higher fungi has not been demonstrated before, as far as the author is aware.

EMULSIN

The presence in plants of an enzyme capable of decomposing glucosides has been known since 1837, and emulsin was discovered in fungi in 1893 by Bourquelot, who found it in *Aspergillus niger,* and by Gerard, who found it in *Penicillium glaucum.* Bourquelot ('94) was able to detect emulsin in many of the higher fungi found on wood. Among those tested, 34 species (mostly *Basidiomycetes*) showed the presence of emulsin, and 9 did not. None of the 9 were found on wood. It is probable that in the destruction of wood, whether frondose or coniferous, glucosides are set free. Among these are salicin, populin, arbutin, and amygdalin from frondose woods, and principally coniferin from the conifers. Before these are available as nutrients for the attacking fungus they must be acted on by emulsin, which splits the glucoside, yielding glucose which is directly assimilable.

In 1895 Bourquelot and Hérissey found that the juice extracted from the sporophores of *Polyporus sulphureus* actively digested the glucosides, arbutin, amygdalin, aesculin, coniferin, and salicin. Working on *Armillaria mellea, Merulius lacrymans,* and *Polyporus squamosus,* Kohnstamm ('01) showed that emulsin is present in the sporophores as well as in an extract of the wood decayed by these organisms. Buller ('06) found the expressed juice of the sporophores of *Polyporus squamosus* to act similarly toward amygdalin, while Bayliss ('08) reported that negative results were obtained using an extract of *Polystictus versicolor.* Reed ('13) reported it from the mycelium of *Glomerella rufomaculans.*

In my experiments a 1 per cent solution of amygdalin was used as a substrate. Ten cubic-centimeter portions of this were placed in test-tubes, and 2 cc. of the enzyme dispersion were added to 3 of these and 1 was boiled. In another, 10 cc. of the amygdalin solution were diluted with 2 cc. of distilled water as a control. To all was added toluol as an antiseptic. All were incubated at 25–30°C. for 3 days. After incubation the two regulars reduced Fehling's solution, gave a strong odor of benzaldehyde and the Prussian blue test for hydrocyanic acid. The boiled control and water control gave none of these tests. The Prussian blue test was not quite as pronounced in the sporophoral as in the mycelial material.

The biological importance of the presence of emulsin in *L. saepiaria* is interesting, since we know that the pine, upon which the fungus grows most readily, contains coniferin. When coniferin is hydrolyzed by emulsin it yields glucose and coniferyl alcohol. The latter, through the action of oxidases, yields vanillin. Glucose is thus made available by the action of emulsin.

Blocks of wood which had been in cultures for one year, during which period they were always saturated with water, were decayed only over the surface. When these were dried in an oven at 65°C. crystals of vanillin were collected over the surface of the blocks and the interior of, as well as about, the apertures of the oven. When the blocks were decayed under moderate moisture conditions no such sublimation of

vanillin was observed. Water then may be a factor to increase this oxidation process in the production of vanillin from woody tissues; at least very moist conditions seem to aid this action or the action of emulsin in the liberation of the coniferyl alcohol.

TANNASE

Knudson ('13, '13[a]), in his two papers on the tannic acid fermentation, gives a review of the literature on this subject up to that time. All of this literature deals with the tannase found in *Aspergillus* and *Penicillium,* but no work has been done to determine tannase in the higher fungi. Knudson, however, did determine the toxicity of tannic acid for fungi, and included in his list such higher forms as *Polyporus sulphureus, P. resinosus,* and *Fomes applanatus.* On 0.25 per cent tannic acid in bean decoction he found *Polyporus sulphureus* and *P. resinosus* to grow well, but no growth was made by any of these forms on 2 per cent tannin.

TABLE VI

STUDY OF THE HYDROLYSIS OF TANNIN BY THE ENZYME DISPERSION FROM LENZITES SAEPIARIA

Amount of enzyme dispersion in 25 cc. of 1 per cent tannin solution	Gallic acid after 4 weeks' hydrolysis		Net over control	
	Mycelium	Sporophore	Mycelium	Sporophore
	mg.	mg.	mg.	mg.
5 cc. dispersion	7.39	5.88	4.1	.....
5 cc. dispersion (autoclaved)	3.28	5.77	.....	.....
5 cc. distilled water	1.31	5.89	.....	.....

To determine the hydrolysis of tannic acid to gallic acid, Jean's ('00) iodine titration method was used. The tannin is precipitated with albumin and salted out with excess of sodium chloride, and the gallic acid remaining is titrated against a standard iodine solution. The value of the albumin solution in terms of the iodine must be subtracted from the gross value of the titration. The experiments follow in table VI. The increase of gallic acid here is very strong and must be regarded as evidence of tannase in the mycelium of the fungus.

DIASTASE

Hartig ('78) was the first to mention the digestion of starch by a wood-destroying fungus, *Fomes annosus,* but not until the work of Bourquelot ('93–'96) did we know that diastase is widely distributed in these higher fungi. Bourquelot's work was especially with the sporophores of *Polyporus sulphureus.* Kohnstamm ('00) demonstrated the presence of diastase in *Merulius lacrymans, Polyporus squamosus,* and *Armillaria mellea,* and in 1906 Buller verified this work with the juice from the sporophores of *Polyporus squamosus.*

Diastase was found present in both the mycelium and sporophores of *L. saepiaria.*

Potato starch was made up into a ¼ per cent paste in the manner which is commonly used in this laboratory in the advanced plant physiology course conducted by Professor Duggar. Two and one-half grams of potato starch in 150 cc. of distilled water were brought to boiling, while constantly stirred. This was transferred to a flask containing about 600 cc. of hot distilled water. The whole was boiled in a reflux condenser for about 2 hours. After cooling the paste was made up to a liter by adding distilled water. To the soluble starch thus prepared about 1 per cent toluol was added as an antiseptic.

A series of experiments was set up as for maltase but using the starch paste as a substrate. After 4 hours the mycelial dispersion showed decided indication of the presence of reducing sugars, while the sporophoral dispersion after 8 hours of incubation showed comparatively less. This work was not quantitative, however, and later experiments were conducted so that quantitative results could be taken. For this work I used the fungous powder prepared from mycelium grown on carrot juice, described under invertase. The fungous powder was used directly without extracting the enzymes. A 1 per cent starch paste was made as above described and this used for the substrate. In each experiment 50 cc. of the paste were used. To this were added 2 grams of the fungous powder and enough toluol to act as an antiseptic. Control experiments were set up in which the fungous powder had been autoclaved.

Parallel experiments were prepared using the ground sporophores. The results of these experiments are incorporated in table VII.

As was the case with the invertase, the diastatic activity shows up much more strongly in the mycelium than in the sporophores.

TABLE VII

QUANTITATIVE STUDY OF THE DIASTATIC ACTIVITY IN MYCELIUM AND SPOROPHORES

Amount of fungous powder in 50 cc. of 1 per cent starch paste	Reducing sugars as glucose in 10 cc. of substrate				Net due to hydrolysis by diastase			
	After 3 hrs. incubation		After 6 hrs. incubation		After 3 hrs. incubation		After 6 hrs. incubation	
	Mycelium	Sporophore	Mycelium	Sporophore	Mycelium	Sporophore	Mycelium	Sporophore
	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.
2 grams powder	10.67	3.18	24.68	7.96	8.50	2.39	22.54	7.20
2 grams powder (autoclaved)	2.17	.79	2.14	.76	.....	.....	.....	.....
Starch paste alone	Negligible	.....	Negligible	.....	.....	.....	.....	.....

CYTO-HYDROLYZING ENZYMES

Under the general term cyto-hydrolyzing enzymes, I shall consider all enzymes which attack such higher carbohydrates as lignin, cellulose, hemicellulose, and pectic bodies. In the succeeding pages the following classification of this group of enzymes will be used:

1. Ligninase, called "hadromase" by Czapek ('99), to designate the enzyme capable of splitting lignin.
2. Cellulase, the true cellulose-hydrolyzing ferment.
3. Hemicellulase, the ferment hydrolyzing the hemicelluloses.
4. Pectase, the enzyme capable of clotting the pectins.
5. Pectinase, an enzyme which hydrolyzes into reducing sugars the pectinous substances, especially the middle lamellae of plant tissues.

Ligninase.—It has often been sought to determine comprehensively the chemical composition of the non-cellulose component of woody membranes. Tiemann and Haarmann, in 1874 (cited from Grafe, '04), believed this component to be coniferin, while Singer ('82) considered lignin as a mixture of coniferin, vanillin, and wood gum, which gave a test for the aromatic aldehydes. The prompt action of Schiff's aldehyde reagent with rose aniline and sulphurous acid speaks for the occurrence of aldehyde-like substances in lignin. In fact, in 1898, Czapek succeeded in splitting off a substance from lignin by cooking it in stannous chloride solution. This substance gave the typical wood reaction when treated with phloroglucin and hydrochloric acid, and was described by him as an aromatic aldehyde which he called hadromal. According to Grafe ('04), Czapek's hadromal does not act like a homogeneous body but like a mixture of vanillin, methyl furfurol, catechol, and coniferin, which substances exist in the form of an ether-like compound with the cellulose of the cell wall, or are taken up by resin, or may be found free in slight amounts in the wood fibre. According to Czapek ('13), however, catechol and vanillin may be regarded as decomposition products of hadromal.

Other authors go only so far as to state that the substances making up lignin are intimately related to colloidal substances, and can exist neither as a chemical compound with cellulose nor as its transformed product. On the other hand, Cross and Bevan ('01) hold that lignocellulose (lignin) is a complex of normal cellulose with two bodies, the one a furfurol-yielding group, the other an aromatic or benzenoid group. Thus the chemistry of the lignocelluloses is such an open question that the decomposition products produced by enzymes from fungi are still worthy of attention.

Our knowledge of the decay of wood induced by fungi practically began with the fundamental researches of Hartig ('78) who has furnished extensive data concerning the parasitic and saprophytic fungi destroying the most important species of wood. He has shown that a radical change in the lignified walls is wrought by the fungus, and that in the first stages of

decay the wood gives a blue color with zinc chloriodid, after which there is a maceration or loosening of the affected walls. That the penetration of the walls by the hyphae is the result of the excretion of active fluids by the fungus was also brought out in this work.

Not only do basidiomycetous fungi attack the lignified walls, but certain filamentous fungi cultivated on wood will penetrate. Miyoshi ('95) found that *Penicillium* and *Botrytis* penetrated the tracheids of the coniferous wood by boring through the bordered pits, while Marshall Ward ('98) showed that by growing *Penicillium* in pure culture on blocks of spruce, the fungus could bore deep into the wood by following the medullary rays in which there was reserve starch. After these more easily assimilable foods are used up the membranes themselves are attacked. Czapek ('99[a]) made similar observations simultaneously with Ward. Hartig observed that the starches disappeared very soon in the presence of the mycelium, as compared with the dissolution of the lignin, which becomes the predominant activity of the fungus.

Czapek ('99[a]) observed that, with alcohol or benzol, a great mass of hadromal can be extracted directly from wood which is destroyed by the inroads of the mycelium of *Merulius lacrymans,* as well as from the wood penetrated by the mycelia of *Polyporus adustus, Pleurotus pulmonarius, P. ornatus,* and *Armillaria mellea.* From sound wood he obtained relatively little hadromal. The alcoholic extract from the decayed wood gives an exceedingly intense red color with phloroglucin acidified with hydrochloric acid. This hadromal test is a permanent thing in all stages of the decay. The test for cellulose by the zinc chloriodid begins to appear before the dissolution of the membrane. Czapek concludes from this that through the action of the fungus the cellulose-hadromal ether is broken, and the cellulose and the hadromal are free to give their individual reactions. To demonstrate that this activity is enzymic, Czapek prepared an extract of the mycelium of *Merulius lacrymans* and *Pleurotus pulmonarius* from natural cultures. Shavings in this extract were incubated at 28°C. There was a gradual action, and after 14 days an alcoholic

extract of these shavings gave a strong hadromal test with phloroglucin and hydrochloric acid. The extracted wood gave the purple reaction with chloriodid of zinc. The fungous extract lost its activity when boiled. It could be precipitated with alcohol and thus yielded a white powder. He called the active principle "hadromase." Von Schrenk ('00, p. 12) isolated the same enzyme from the mycelium of *Polyporus subacidus* growing in spruce wood.

After taking into consideration the different types of wood decay, it would seem that "hadromase" is a misnomer, since it does not act upon hadromal but upon lignin. In some forms of decay, such as the action of *Trametes Pini* upon pine (see Hartig, '78, p. 36, and von Schrenk, '00[a]), the white rot of the red cedar produced by *Polyporus juniperinus* (see von Schrenk, '00, p. 9), and the action of *Thelephora perdix* on the oak, as reported by Helbig ('11) the hadromal and other bodies are split up and used by the causal organism, leaving pure white cellulose. Should an enzyme which acts on hadromal, or the soluble substances giving this red phloroglucin test ever be isolated in these cases, it would lead to a confusion in nomenclature. It is proposed that "ligninase" be used to designate the enzyme capable of splitting lignin.

A lengthy list of papers may be cited which deal with timber-destroying fungi and which refer in a direct or indirect way to the lignin-splitting enzyme. Among these publications which have not been cited above may be mentioned the work of Biffen ('01) on the biology of *Bulgaria polymorpha,* of Marshall Ward ('97) on cultures of *Stereum hirsutum,* of Buller ('05) on the destruction of paving blocks by *Lentinus lepideus* Fr., and ('06) *Polyporus squamosus* as a wood destroyer, of Falck ('09, '12) on the dry rots of *Lenzites* and *Merulius,* of Wehmer ('12, '14), and various papers by von Schrenk ('00, '00[a], '00[b], '01, '03, '14, '14[a]). Whether the authors mentioned here have isolated the enzyme or not, it is probable *a priori* that the lignin-splitting enzyme is present in the fungi with which these papers deal.

Since *Lenzites saepiaria* produces a typical brown rot similar to that produced by other dry rot fungi, such as *Merulius*

lacrymans, I was interested in the stages of decay and the enzymes involved in the destruction of the wood. In addition to the study of the enzymes, observations were made on the microchemical reactions of the sound, and various stages of the decayed, wood. These last are reported in this paper immediately after the discussion of the cytolytic enzymes, for the decay is more directly a result of these enzymes.

The following are the experiments carried out in the laboratory to determine the production of ligninase by *Lenzites,* and incidentally showing the action of cellulase.

One gram of fine shavings of the sap-wood of *Pinus echinata* was placed in each of 3 test-tubes. The shavings had previously been soaked in distilled water for 48 hours to remove as much of the soluble substances as possible, and subsequently dried. To 1 tube were added 15 cc. of the enzyme dispersion from the mycelial meal and 15 cc. of distilled water, to the second tube 30 cc. of distilled water, and to the third 15 cc. of distilled water and 15 cc. of the enzyme dispersion which had been autoclaved up to 10 pounds pressure. To all a few drops of toluol were added.

Fifteen days later the liquid was decanted from the shavings and filtered. The shavings were boiled in absolute alcohol for 10 minutes, after which the alcohol was decanted off and tested for Czapek's hadromal. With the addition of phloroglucin and hydrochloric acid, the first gave a pink color, while the second and third gave clear, colorless tests.

Some of the sections (shavings) were subsequently stained with phloroglucin and hydrochloric acid and others with chloriodid of zinc. Shavings from the first tube were stained a deep red with phloroglucin and hydrochloric acid, but with chloriodid of zinc there was a yellowish color given to all the layers of the walls. Shavings from the second and third tubes gave the same color reaction with the phloroglucin as those from the first tube, but with the zinc chloriodid the lamella next to the lumen was stained a light purple, while the outer lamellae of the wall took a yellowish color. These reactions show conclusively that hadromal is split off in the presence of an enzyme preparation from the mycelium of *L. saepiaria;*

that the same enzyme preparation is capable of hydrolyzing the free cellulose of the inner lamellae and leaving only such substances as will give a yellow reaction with chloriodid of zinc; and that the active substance in the preparation is thermolabile.

The aqueous solution, just as it was filtered from the shavings, reduced Fehling's solution; that from the second and third tubes reduced Fehling's somewhat, but in comparison not so strongly as that from the first. Thus, quantitative determinations were made to decide whether the reducing substances were due to enzyme action or possibly to the presence of other reducing substances already in the wood, as, for instance, tannins.

To this end 10 cc. of the aqueous solution from each were placed in Erlenmeyer flasks of 125 cc. capacity. A fourth determination was made as a control on the Fehling's solution. The determinations of reducing sugars were made as glucose by the Shaffer method ('14). Table VIII gives the results obtained:

TABLE VIII

REDUCING SUGARS DUE TO ENZYME ACTION OF LENZITES SAEPIARIA ON PINE SHAVINGS IN 15 DAYS

Tube number	Experiment	Reducing substances as glucose	Net above controls
		mg.	mg.
1	1 gm. pine + 15 cc. enzyme dispersion + 15 cc. distilled water	10.606	8.973
2	1 gm. pine + 30 cc. distilled water	1.492	.....
3	1 gm. pine + 15 cc. enzyme dispersion (autoclaved) +15 cc. distilled water	1.633	.....
4	Fehling's solution alone	Negligible	.....

The results obtained here show that these reducing substances are due to enzyme action, and that they must be sugars, probably glucose and other monosaccharides. The sources of this glucose may be various. There is probably some tannin, although slight, in sap-wood. Besides this there is the hydrolysis of cellulose to reducing sugars, as demonstrated by the experiments reported later on cellulase. Then

there are probably some starches of the medullary rays hydrolyzed by diastase, and coniferin hydrolyzed by emulsin, yielding glucose and coniferyl alcohol.

To amplify the results obtained above, a few pieces of a pine block which had been in pure culture of *L. saepiaria* for a period of 6 months were extracted with absolute alcohol for 10 minutes, and the amber-colored extract yielded a deep red, with the addition of phloroglucin and hydrochloric acid.

A quantity of wood from a railroad tie decayed by *L. saepiaria* was extracted with alcohol for 10 hours in a reflux condenser. The filtered alcoholic extract obtained in this way was of a deep amber color. When a small portion was diluted to 2 volumes with alcohol and tested with phloroglucin and hydrochloric acid, it gave a deep sherry-red. When the alcoholic extract was evaporated to dryness a hard amber-like residue remained. This breaks with a conchoidal fracture, and seems to be identical with Czapek's hadromal.

These results on a typical brown rot are the same as those found by Czapek ('99[a]) for the brown rot produced by *Merulius lacrymans;* that is, there is a substance, which gives the lignin reaction, set free by enzyme action. In the case of Lenzites decay, however, the cellulose disappears as rapidly as it is set free, and in this respect the action is more rapid than in *Merulius.*

The same type of experiment was repeated, using the enzyme dispersion prepared from the sporophoral meal, but there were no results worthy of mention, other than the fact that the shavings in all cultures gave the same tests as were obtained in the water control in the above series. Quantitative determinations of reducing sugars were not considered worth while, as the reduction of Fehling's solution was so slight that no visible copper oxide was thrown down.

Cellulase.—True or normal cellulose forms the groundwork of the plant cell wall in most instances. It is a complex carbohydrate of the formula $(C_6H_{10}O_5)_n$. It is distinguished by its great resistance to hydrolysis and its insolubility in most chemical solutions. To the researches of Cross and Bevan ('01[a], '06, '12), we are indebted for a great deal of our knowl-

edge of the celluloses. A full review of the chemistry of cellulose is given by Schwalbe ('11) in a very comprehensive way. It suffices to say here that the decomposition products of cellulose are mono- and disaccharides, and the decomposition may be brought about more or less readily, according to the complexity of the cellulose molecules, by the action of acids or alkalis and by the hydrolysis due to enzyme action.

An adequate review of the literature concerning the rôle of microörganisms and filamentous fungi in the fermentation of cellulose, especially in the soil, may be had by recourse to the papers by Kellerman and McBeth ('12) and McBeth and Scales ('13). Much of the literature on early experiments with parasitic fungi and their ability to pierce the cell membrane is reviewed in the above-mentioned papers, as well as by Cooley ('14). Space will permit only a brief review of some of the more important later papers dealing more closely with the destruction of the true cellulose of wood fibre after it is set free from the lignocellulose.

Czapek ('99[a]) found in the decay produced by *Merulius lacrymans* that the cellulose disappeared from the cell walls, and he concluded *a priori* that a cellulose-hydrolyzing enzyme was excreted by the fungus, although he was unable to demonstrate it experimentally. Ward ('97) observed that in the progress of wood destruction due to *Stereum hirsutum* the action proceeds from the lumen outward. The sound wood (*Aesculus*) gives no cellulose test, but the first signs of dissolution are the swelling of the layers next to the lumen and the separation of the lumen from the layers next to the middle lamellae. These swollen layers give the test for cellulose, and as they disappear the next layer becomes delignified, gives the cellulose test, and finally disappears. The middle lamellae remain untouched. Ward did not attempt to isolate the enzyme which hydrolyzed the cellulose. According to Buller ('05), wood is rotted by *Lentinus lepideus* in much the same manner as by *Merulius* and *Stereum*. It shrinks and cracks on drying, and is then very brittle and friable. The free cellulose is removed by the fungus.

It seems from experiments carried out by Kohnstamm ('01) that the juice of *Merulius lacrymans,* expressed according to Buchner's process, gave evidence of the existence of a true cellulase. He found, that after 50 hours of action of the expressed juice on leaves of *Elodea,* there was a corrosion in the form of fine lines extending out from definite spots in the walls. These streaks soon became thin, and the walls appeared to be obliquely marked with alternate light and darker lines. He mentions that this corrosion in these definite lines, which are always in the same direction, is influenced apparently by the micellar structure of the cell walls.

Buller ('06) attempted to prove the presence of cellulase in the sporophores of *Polyporus squamosus* in the following way: Thin sections of barley grains, which had been cleared of starch by means of the action of saliva, were placed in the fungous extract. No indication of cellulase was obtained, but owing to the disappearance of the cellulose from diseased wood, he assumed that the vegetative part of the fungus produced abundant cellulase.

In Falck's ('09, p. 156) discussion of the destruction of fir, pine, and spruce wood by means of *Lenzites,* he says that in the beginning of the destructive stages the lignin reactions are decreased, and in the last stages they have almost completely disappeared, but that the reactions for cellulose are negative in all stages of decay. On the other hand, in dealing with the same fungus Spaulding ('11) says that "phloroglucin and hydrochloric acid give a bright red in the rotted tissues. . . . . Chloriodid of zinc gives a blue color only in part of the tissues in early stages of the disease, but in later ones it gives blue throughout." This would seem to indicate that the fungus had disorganized the lignocellulose, but had left the free cellulose and most of the hadromal.

Reed ('13) grew *Glomerella rufomaculans* upon a nutrient solution containing strips of filter paper. There was considerably more growth in the flasks containing cellulose than in the controls. At the end of 2 months there was somewhat more than 3 times as much dry fungous matter in the regular as in the controls. The solution gave no tests for reducing

sugars, which were probably utilized by the fungus as fast as they were split off.

Wolf ('16) made poured plates of cellulose agar which he inoculated with species of *Pseudomonas, Phoma, Gloeosporium,* and *Fusarium.* He says: "There was no evidence of the production of cellulase except by *Phoma.*" Samples of normal tissues and of tissues diseased by *Phoma socia* Wolf were tested for cellulose by employing Schweitzer's reagent, and Wolf observes that "there is a slight but significant decrease in the amount of cellulose found in diseased tissues." A considerable number of determinations consistently showed that "the lesser amount of cellulose was invariably found in the diseased tissue."

Further experiments were instituted, since it was clear from microchemical tests and from the above experiments on ligninase that cellulose of attacked wood disappears. In order to test out the action of the enzyme preparations on normal cellulose, pure cellulose from two sources was prepared. One was prepared from filter paper in the way described by McBeth and Scales ('13) and later by Cooley ('14). Fifteen grams of filter paper were dissolved in Schweitzer's reagent and precipitated with dilute hydrochloric acid. After washing thoroughly with dilute acid to get rid of all of the copper and then with distilled water to get rid of all of the chlorine, a very flocculent cellulose precipitate was obtained. The water was filtered off with a Buchner funnel until the cellulose suspension was concentrated to about 500 cc. This was transferred to a liter flask which was plugged and sterilized.

Another type of pure cellulose was made from pine wood. A quantity of fine pine shavings were treated with a cold solution composed of 30 grams of potassium chlorate dissolved in 520 cc. of nitric acid (sp. gr. 1.1). The container was kept cold for 4 weeks, after which time the cellulose was washed and then precipitated from Schweitzer's reagent, as in the above case. It was sterilized and kept for future use, as was the filter paper cellulose.

Several types of cellulose agar were prepared, using both the filter paper cellulose and the pine wood cellulose. Some

standard nutrient solutions for the artificial culture of fungi were used as a basis for these, such as:

(1) Richards' ('97) solution, substituting 100 cc. of the 2 cellulose suspensions for cane sugar and adding 2 grams of agar.

NH_4NO_3	1.0	gram
KH_2PO_4	0.5	gram
$MgSO_4$	0.25	gram
Fe_2Cl_3	0.002	gram
Cellulose suspension	100	cc.
Agar	2	grams

(2) Cooley's solution "A," just as given by Cooley ('14, p. 306).

(3) Reed's solution, as given by Reed ('13, p. 69), with the exception of using one-half as much distilled water together with 500 cc. of cellulose suspension and 2 per cent agar.

On any of these agars *L. saepiaria* grows very slowly and without producing much of a mat. Wherever cellulose hydrolysis could be seen it was very, very slight, and this was only in cases where the pine wood cellulose was used.

Since these experiments gave such meagre results 2 per cent agars were made, using dilute extracts of carrot, turnip, and potato as bases and using cellulose suspensions in approximately the same concentrations as in the above. In this series of experiments the cloudiness of the agar due to cellulose suspension was cleared up noticeably in one case only. This was where carrot-pine-wood-cellulose agar was used. The agar was tubed and sterilized in test-tubes of 13 mm. diameter. The agar was not slanted, and after inoculation the tubes were kept in a damp chamber so that the water content of the agar would remain the same throughout incubation. These tubes were kept at a temperature of 32°C. for 4 weeks. After this length of incubation the agar had cleared to an average depth of 9 mm. in the inoculated tubes where carrot-pine-wood-cellulose agar was used. The uninoculated tubes were still uniformly cloudy. There was no hydrolysis in the tubes where carrot juice was not used. The most significant fact brought out in this series of experiments is that

the pine wood cellulose is hydrolyzed by the cellulase excreted by *L. saepiaria,* while the filter paper cellulose remained untouched.

Experiments with the enzyme dispersion were set up according to the scheme as outlined in table IX. All of the experiments were set up in duplicate with both sporophoral and mycelial dispersions. Toluol was used as an antiseptic, and qualitative results were taken after 4 weeks.

TABLE IX

QUALITATIVE EXPERIMENTS SHOWING THE ACTION OF MYCELIAL AND SPOROPHORAL ENZYME DISPERSIONS ON FILTER PAPER CELLULOSE AND PINE WOOD CELLULOSE

Experiment	Reduction of Fehling's solution	
	Mycelium	Sporophore
10 cc. paper cellulose + 2 cc. dispersion	+ +	+
10 cc. pine cellulose + 2 cc. dispersion	+ + + +	+ +
10 cc. pine cellulose + 2 cc. dispersion (autoclaved)	+	—
10 cc. paper cellulose + 2 cc. dispersion (autoclaved)	+	—
10 cc. paper cellulose + 2 cc. distilled water	—	—
10 cc. pine cellulose + 2 cc. distilled water	—	—

Since such definite results were obtained with the mycelial enzyme dispersion in the foregoing experiments, it was determined to make quantitative comparisons of the activity of cellulase in the sporophoral and mycelial tissues. To this end a carrot extract was made as described above under "invertase," and to this extract was added pine wood cellulose. This nutrient solution was placed in Erlenmeyer flasks, which were plugged, sterilized, and inoculated as described for invertase and diastase. The mats of mycelium formed after 2 weeks were removed from the flasks, dried, and ground to a fine powder which was used in the following way: To 50 cc. of the pine-cellulose suspension were added 2 grams of the mycelial powder with toluol as an antiseptic. Some of the mycelial powder was autoclaved, and controls on the above were prepared with this autoclaved powder as well as with distilled water alone. These experiments were set up in duplicate. A parallel series was prepared using the sporophoral tissue powder. After incubating these enzyme cultures at about

28° C. for 4 weeks the sugar content of the substrates was determined as glucose by the Shaffer method already mentioned. The results of these determinations are reported in table x.

In the light of these results, there is no doubt that cellulase is present in the mycelium of *Lenzites* and that its activity can be measured quantitatively. The little activity shown in the fruiting bodies is probably due to the small amount of superficial mycelium which was removed from the substrate

TABLE X

QUANTITATIVE DETERMINATIONS OF SUGAR PRODUCED BY THE CELLULASE OF LENZITES SAEPIARIA

Amount of tissue powder in 50 cc. of pine wood-cellulose suspension	Reducing sugar as glucose in 50 cc. of substrate after 28 days		Net glucose above controls	
	Mycelium	Sporophore	Mycelium	Sporophore
	mg.	mg.	mg.	mg.
2 grams powder	6.479	0.99	3.271	0.28
2 grams powder (autoclaved)	3.028	0.71	.....	.....
Cellulose suspension alone	Negligible	.....	.....	.....

when the sporophores were collected. It is almost impossible to get purely fruiting tissue without some such closely connected vegetative tissue, and it is also impossible to say whether or not the enzymes diffuse from the adjacent mycelium to the base of the fruiting bodies.

A series of quantitative cellulose determinations has been made to establish further the cellulase activity in *L. saepiaria.* It was thought that possibly there might be established some relation between the percentage in reduction in weight due to decay by the fungus and in the loss in cellulose due to the cellulase, or some relation between either of these and the specific weight of the substrate. But three determinations with their controls have been made. Blocks of yellow pine, approximately $1\times1\times2$ inches, were dried to constant weight and weighed, and the volumes were taken by immersion in mercury. From these figures the specific weight was computed. These blocks were sterilized in jars plugged with cotton, inoculated with *L. saepiaria,* and incubated under

favorable moisture and temperature conditions for one year. After this period they were dried, and the percentage of reduction in weight due to fungous decay was determined. Control blocks of the same specific weight and from the same samples were kept in a sound condition.

To make the cellulose determinations the blocks from the cultures and the controls were planed into fine shavings. All of the shavings from each sample were placed in a 250-cc.

TABLE XI

QUANTITATIVE DETERMINATIONS OF CELLULOSE FROM BLOCKS OF PINE WOOD, BOTH SOUND, AND DECAYED BY LENZITES SAEPIARIA

Sample number	Condition	Specific weight	Original weight of wood	Weight of wood after decay	Per cent reduction in decay	Weight of cellulose	Per cent of cellulose	Per cent loss in cellulose
			gm.	gm.		gm.		
O 5	Decayed	.424	13.373	6.973	47.86	0.9563	13.714	43.057
O 5	Sound	.424	8.55	.....	.....	2.0592	24.084	.....
F 5	Decayed	.419	12.580	8.494	32.48	1.2952	15.248	38.187
F 5	Sound	.419	9.31	.....	.....	2.3066	24.668	.....
A 24	Decayed	.547	12.418	5.84	52.97	0.1943	3.327	75.654
A 24	Sound	.547	7.100	.....	.....	0.9703	13.666	.....

Erlenmeyer flask containing about 125 cc. of the solution of potassium chlorate in nitric acid mentioned above. These were placed in an ice chest for 3 weeks, after which time the contents of each flask was diluted to about 3 liters. The diluted liquid was thus weak enough not to attack a filter paper while filtering. The liquid was filtered off through a Buchner funnel containing a tared filter paper. The cellulose thus obtained was repeatedly washed with hot distilled water until it was of a pure white color and gave a deep blue reaction with zinc chloriodid. In all cases the yield of cellulose was so clear of foreign material that it was deemed unnecessary to precipitate from Schweitzer's reagent. After drying and weighing, the percentage loss in cellulose due to the action of the fungus was determined. The different factors in this experiment are tabulated in table XI.

In these 3 determinations there seems to be no definite relation between the percentage loss of cellulose and the percent-

age reduction in weight due to fungous decay. This may be due to different proportions of lignification in the different samples, or more likely, since other substances like coniferin, hadromal, and possibly vanillin are utilized by the fungus, the total reduction would not necessarily bear any definite relation to the reduction of any one of the complex. Helbig ('11) has made similar cellulose determinations on wood which had been altered by *Thelephora perdix*. This fungus produces a white rot, and Helbig found that with the advance of decay the percentage of cellulose increases perceptibly.

Hemicellulase.—The hemicelluloses differ from the true celluloses in that they are more easily hydrolyzed, are readily dissolved in hot dilute acids, and sometimes give a blue color with iodine. Their chemical compositions are determined by the products of their hydrolysis. They may yield dextrose, mannose, galactose, or mixtures of these, and at times xylose or arabinose. According to these decomposition products, they are differentiated into dextrans, mannans, galactans, mannogalactans, etc. Very frequently hemicelluloses are deposited upon, or as a part of, cell walls, and here play the rôle of reserve foods, especially in seeds.

Newcombe ('99) determined that the cellulose-hydrolyzing enzyme is distinct from other carbohydrases. Schellenberg ('08), through experiments on numerous fungi, also proved that pure cultures grown on substrates containing hemicelluloses and true celluloses would hydrolyze hemicelluloses but not the true celluloses. He also shows that the moulds act selectively toward the hemicelluloses from various sources. He thus differentiates between the different hemicellulases which act on various hemicelluloses, and the cellulase which hydrolyzes the true cellulose.

To ascertain whether the enzyme dispersions from mycelium and sporophores are active as hemicellulose-hydrolyzers, the endosperm of the date seed (*Phoenix dactylifera*) was used as a substrate.

Date seeds were scraped to remove the outer coats, and then were thoroughly washed with sand and soap to remove all reducing sugars possible. The seeds were then rinsed in dis-

tilled water, cracked, and the embryos removed. The hemicellulose thus prepared was autoclaved in distilled water at 12 pounds pressure for 20 minutes to kill all enzymes present. The water was again decanted off, and the endosperms rinsed and allowed to remain in distilled water with toluol to preserve for future use.

Van Tieghem cells were prepared, and very thin slices of hemicellulose were suspended in hanging drops of enzyme dispersion, as follows:

(1) Eight cells with hanging drops of mycelial dispersion.

(2) Eight cells with hanging drops of sporophoral dispersion.

(3) Four cells with hanging drops of autoclaved mycelial dispersion.

(4) Four cells with hanging drops of autoclaved sporophoral dispersion.

(5) Four cells with hanging drops of distilled water.

In the bottom of each cell was placed enough of the solution of the same vapor tension as the hanging drop, so that evaporation of the drops was prevented. A drop of chloroform was added to each cell as an antiseptic. These cells were examined from time to time, but no sign of the erosion of the hemicellulose was noticed until after 25 days. There was a slight indication of erosion in five of the drops of mycelial dispersion. The other three were contaminated with bacteria and showed slight erosion. There was no erosion in the controls except in one contaminated with bacteria. After 40 days three of the five drops of mycelial dispersion observed 2 weeks before were still perfectly aseptic, and two had dried down. The pieces of hemicellulose in the three cells were strongly eroded. In places only a granular substance was left. When the cover glasses were removed from these three cells there was a strong odor of chloroform still remaining in each. That they were perfectly aseptic was proven by removing from the drop what remained of the slice of hemicellulose, drying down the hanging drops on the cover slips, and flaming and staining the smear with gentian violet. There were no bacteria or fungi present. There was no erosion in any of the

cells containing the enzyme preparation from the sporophores nor in the cells containing the mycelial dispersion which had been autoclaved. These results go to show that there is hemicellulase in the mycelium of *L. saepiaria* but not in the tissues of the fructifications.

Another experiment was conducted as follows: Four test-tubes each were prepared with mycelial and sporophoral dispersions in the following manner:

(1) 0.5 gm. hemicellulose+10 cc. enzyme preparation+toluol.

(2) 0.5 gm. hemicellulose+10 cc. enzyme preparation+toluol.

(3) 0.5 gm. hemicellulose+10 cc. enzyme preparation (autoclaved)+toluol.

(4) 0.5 gm. hemicellulose+10 cc. distilled water+toluol.

These were incubated at 25–30°C. for 25 days, after which the liquid was filtered off and 5 cc. from each were tested with Fehling's solution for reducing sugars. Numbers 1 and 2 showed slight reduction of copper produced by the mycelial dispersion but not by that from the sporophores. In the controls no copper oxide could be detected.

From these results it is certain that the mycelium contains the enzyme, hemicellulase, capable of hydrolyzing the hemicellulose of the endosperm of *Phoenix dactylifera*. This hemicellulose is a paragalactan, which, on hydrolysis, yields a mixture of galactose and arabinose, both of which reduce Fehling's solution.

Pectase and pectinase.—Closely allied with cellulose is a group of substances called pectic bodies. Pectose is the name given to the parent substance of bodies, such as pectin, pectic acid, etc. Many fruits, such as apples, gooseberries, currants, cranberries, and fleshy roots—such as carrots—contain a substance soluble in water but gelatinizing in alcohol. This substance which causes the juice of fruits to "jell" is known as pectin. A solution of pectin gelatinizes on standing, probably due to the action of the enzyme, pectase, contained in the fruit juice.

Mangin ('92, '93) investigated the pectose group of substances and divided them into two groups: first, neutral bodies varying in their solubility in water from pectose, which is insoluble and closely resembles cellulose, to pectin, which is soluble but readily forms a jelly; second, acid bodies, chiefly pectic acid, the latter occurring as calcium pectate, forming the middle lamellae of plant tissues. The enzyme which is capable of hydrolyzing the pectic bodies is generally termed pectinase, while the one causing coagulation is pectase.

It is a well-known phenomenon in certain types of decay that the middle lamellae disappear. As early as 1886, de Bary ('86) observed that the mycelium of *Peziza sclerotiorum* was capable of penetrating cell walls and gelatinizing them. The juice of the sclerotia of this fungus had the power to dissolve the middle lamellae and gelatinize the inner layers of the cell walls of turnips and carrots. The enzyme preparation precipitated from the juice by means of alcohol affected the cell walls in the same way.

Ward ('88) observed the macerating action of the *Botrytis* causing the lily disease. These observations were made on sections of the leaves, petioles, and ovary of the lily. The middle lamellae underwent dissolution in a few hours when placed in aqueous extracts of the fungus. Since Jones ('05) and Cooley ('14) have so amply reviewed the earlier work in this field, it will not be discussed further in this paper. Cooley ('14) shows that in tubes containing pectin a coagulum was produced by *Sclerotinia cinerea*, thus showing the excretion of pectase by this fungus, which, nevertheless, shows no particular affinity for the middle lamellae. On the other hand, Brown's ('15) work with *Botrytis cinerea* shows this fungus to possess the power of dissolving the middle lamellae. The enzyme extract prepared from very young mycelia brought about a very rapid disintegration in the tissues of potato, turnip, beet, apple, etc. Discs of these tissues were disorganized in from 15 to 90 minutes. The death of the cells did not take place until some time after they had been separated by the solution of the middle lamellae. The activity of the extract was destroyed by heat.

No work on wood-destroying forms has demonstrated the presence of an enzyme capable of disorganizing the middle lamellae, although many of the decays show maceration. Spaulding ('11) says that in the last stages of decay produced by *Lenzites saepiaria* the middle lamellae have disappeared.

Since it was found in microchemical observations that the middle lamellae of the wood decayed by *L. saepiaria* were dissolved out, it was attempted to demonstrate pectase and pectinase experimentally. Pectin was prepared in the usual way by the action of alcohol on the juice expressed from cranberries. Pectase from the carrot coagulated this pectin, but only negative results were obtained with the enzyme dispersions from *L. saepiaria.* Further experiments were conducted to determine the macerating power of the dispersions on various tissues.

Slices of carrot, potato, and beet were cut to a uniform thickness. From these slices discs were cut by means of a cork-borer, and similar discs were also prepared from very young tobacco leaves. As a source of enzymes, the mycelial powder prepared from mycelium grown on carrot juice was used. Two grams of this powder were soaked in 50 cc. of distilled water for 5 hours, after which the liquid was decanted off. The four kinds of discs mentioned above were placed in portions of this liquid in closed stenders and a few drops of toluol added to each. Discs were also kept in distilled water as controls. Observations were made after 18 hours. Carrot discs in the mycelial extract had lost in coherence in comparison with those in the distilled water. When pulled apart the latter were torn as much across the cells as following the cell walls, while in the former the separation followed the line of the cell walls. Beet discs showed no maceration whatever after 18 hours. Potato discs showed a more marked maceration than the carrot. The potato had become very flaccid in the extract. The discs of tobacco leaves showed no loss of coherence. After 42 hours the carrot discs and potato discs had lost all coherence, and the cells were easily pressed apart under a cover glass. In the controls in

distilled water there was no diminution of coherence of the tissues. Thus, the presence of pectinase may be demonstrated in the mycelium of *L. saepiaria,* while there are no indications of the presence of pectase.

The effect of the cyto-hydrolyzing enzymes as demonstrated by microchemical observations on the sound and decayed wood.—Pine wood is composed of tracheids with one row of bordered pits in the radial walls. The annual rings are usually well differentiated into spring and summer wood, especially in the heart. Resin ducts occur among the tracheids, extending longitudinally, as well as radially, in the medullary rays. The resin ducts are surrounded with wood parenchyma. The sap-wood is lighter in color than the heart, probably due to oxidation, since the lumen of the heart tracheids are well aërated, as well as to the presence of tannoid bodies which become darker with continued exposure to air. The sap-wood, of course, is not so thoroughly lignified as the heart-wood, and often the inner lamella gives the cellulose test with zinc chloriodid.

The wood that has been attacked by *L. saepiaria* is darker in color than the sound wood; it is also very brittle and when crushed between the fingers breaks into a fine powder. It is evident that marked changes take place in the wood due to the action of enzymes produced by the fungus. To determine what some of these changes are and something about their sequence, I resorted to microchemical tests. To this end sections of sound wood and wood in various stages of decay were examined. Free-hand sections were made longitudinally, but in the later stages of decay it is impossible to cut transverse sections because of the brittle character of the tissues. Small pieces, carefully cut down to 0.5-cc. cubes, were imbedded in celloidin, and from these then the free-hand, transverse sections were cut.

The sound sap-wood gave the following tests:

(1) An alcoholic solution of phloroglucin with an addition of hydrochloric acid gave a deep red in the middle lamella, dark red in the secondary, and pink in the tertiary lamella.

(2) After soaking sections in iodine and then treating with 65 per cent sulphuric acid, the secondary lamella was a yellow to brown color, with a purple lining in the early spring wood.

(3) Chloriodid of zinc gave a brown coloration both in the spring and summer wood, with a slight blue tint lining the tracheids in the sap-wood.

(4) Aniline sulphate produced a bright yellow which increased in intensity from spring to late summer wood.

(5) After treating with potassium hydroxide for some time and then applying the cellulose tests the following results were obtained:

(a) After continued action of iodine followed by the addition of sulphuric acid, the inner or tertiary lamella was swollen and shrunken away from the secondary, the former assuming a purple color.

(b) Chloriodid of zinc colored the swollen tertiary lamella blue, while the main part of the wall was brown.

(6) Resorcin and sulphuric acid gave a violet to blue reaction in the lignified walls.

When these same tests were applied to the decayed wood some difficulty was found, especially where the tests yield yellow or brown, because the tissues were decidedly brown in the last stages of decay. If a transverse section is made through a decayed portion of wood so as to include a part of the sound, normal wood, the progressive stages of decay may be followed by applying the above stains.

When phloroglucin and hydrochloric acid are applied to such a section, it is noticed that chemical changes have preceded any visible or microscopical changes in structure. In the sound wood the secondary and tertiary lamellae are stained a dark red, while the middle lamella is a still darker red. A little nearer the edge of the decayed region the red has changed to a maroon or brownish red in the tertiary lamella. As we proceed nearer to the decayed portion this maroon increases until the secondary lamella is all brownish red, and the middle lamella only remains the brighter red with

this stain. In radial sections it may be noticed that this maroon discoloration starts from the bordered pits, especially if they are perforated with fungous hyphae. The hyphae seek the bordered pits, these apparently serving as the only places where the hyphae pass from one lumen to another.

In the tangential section the discoloration in the earliest stages occurs only in the neighborhood of the medullary rays. While this discoloration is taking place the tertiary lamella first contracts and then practically disappears. The secondary lamella likewise shrinks as it takes on this brownish red color. This must be due to the gradual hydrolysis of cellulose and probably the simultaneous hydrolysis of coniferin through the action of emulsin. The secondary lamella shrinks, but in the last stages of decay there are still brown, fragile remains of this layer, together, undoubtedly, with infiltrated by-products from the decayed middle and tertiary lamellae. The middle lamella seems to disappear almost simultaneously with the decay of the secondary.

With chloriodid of zinc the decayed wood gives the same test as in the sound wood, a brown color. This is true in all stages of decay. There is no indication of free cellulose at any time during decay. Partially delignified sections, cut from the same surface as the sections on which the above lignin tests were made, were treated with a 5 per cent potassium hydroxide for some time. On the addition of chloriodid of zinc the lamellae yielded a purplish blue reaction, where only partially delignified by the fungus; but where decay was complete a brown color was obtained. These results show that the first step is the splitting of lignin, and simultaneously with this there is a complete hydrolysis of the cellulose as fast as it is set free. Undoubtedly some of the substances giving the lignin reaction are also used up.

Other lignin tests gave similar results. The action of aniline sulphate was marked. The sound wood was colored yellow, and as the diseased region was approached the color became browner, although the yellow element did not seem to be lost entirely. Indications are that in the decayed wood some of the substance that gave the lignin reaction still

remained. This was easily extracted and is what Czapek has called "hadromal." The iodine-sulphuric acid test for cellulose corresponds well with what we found with zinc chloriodid —a light brown color.

Our microchemical tests applied to the decayed wood substantiate in the main the results obtained with the enzyme dispersions and other enzyme preparations, i.e., that cellulase and ligninase are secreted by *L. saepiaria.* Pectinase is both demonstrable *in vitro* and in nature, the pectinase of the middle lamella disappearing with the action of the fungus.

A point of further interest is the composition of the brown substance left after the complete decay of the tracheids. This is a brittle substance which is easily crushed into a fine brown powder. A quantity of this brown material secured from the decayed cavities of an old railroad tie was ground as finely as possible in a mill, and to this powder was added a dilute alkali. After soaking for 2 days the alkali was filtered off, and by adding acid to the filtrate a flocculent precipitate was thrown down. When dried down this precipitate shrinks and cracks. It is insoluble in chloroform, alcohol, ether, acetone, and petroleum ether, but is readily redissolved in alkali and may be reprecipitated with acid. This substance partakes of the nature of "humus" compounds. The remainder of the brown powder is much like "peat."

In the disease of *Taxodium distichum* known as "pecky" cypress, von Schrenk ('00[b]) found a similar substance which he called a humus compound. In the case of *Taxodium* the humus compounds are in a liquid form, and thus are deposited in the tracheids where the mass dries and cracks, "looking much like mud which has dried in the sun." The humus liquid infiltrates into the sound wood immediately surrounding the decayed spots and darkens the wood in the decayed regions. Undoubtedly, the humus compounds found in wood decayed by *Lenzites* and by the fungus causing the peckiness of cypress are a direct result of the activity of the enzymes concerned in the decay.

It was mentioned above that in the process of delignification, etc., the shell of the tracheids remaining after the last stages

of decay shrinks and cracks. The cracks in the walls always follow the same general direction and seem to begin with the bordered pits. The slits are spiral in form and pass obliquely across the pits from left to right upwards. By changing the focus these lines are from right to left upwards on the farther wall of the tracheid. Von Schrenk ('00[b]) also observed this in the tracheids of *Taxodium distichum* infected with "peckiness." In the erosion of the cell walls of Elodea leaves, due to the action of an enzyme preparation from *Merulius lacrymans,* Kohnstamm ('01) noticed that the action took place in definite lines. He is inclined to believe that this is due to the micellar structure of the cell walls.

In general, the Lenzites decay is of the same type as that produced by *Merulius lacrymans* and reported on by Czapek ('99), but the hydrolysis of the cellulose is much more rapid in the former. In contrast to this type we have the other extreme represented by the pin rot of pine due to *Trametes Pini,* the white rot of cedar due to *Polyporus juniperinus,* and the rot of oak produced by *Thelephora perdix.* In this case, as mentioned before, all substances are used by the fungus with the exception of cellulose which is left as a pure white by-product.

INULINASE

Inulinase was discovered by Green ('88) in the Jerusalem artichoke (*Helianthus tuberosus*). It was first demonstrated in fungi by Bourquelot ('93) who found it in *Aspergillus niger,* but later with Hérissey ('95) did not find it in the sporophores of *Polyporus sulphureus.* Dean ('03) verified Bourquelot's work with *Aspergillus niger* and *Penicillium glaucum* and found inulinase to be an intracellular enzyme. Dox ('10) reported that *Penicillium Camemberti* had slight action on inulin unless cultivated on a substrate containing inulin as the source of carbon. In this case inulinase was produced more abundantly.

In our experiments with *Lenzites* the enzyme preparations from the mycelium and the sporophores were used. To 10 cc. of a 1 per cent solution of inulin 2 cc. of the enzyme dispersion were added and toluol used as an antiseptic. There was a

marked reduction of copper oxide from Fehling's solution after 2 days of incubation at 25–30°C., while the boiled controls and water controls showed no reduction. The inulinase seemed to be quite active in both the mycelium and sporophores, but no quantitative comparison was made.

AMIDASE AND UREASE

Since we found positive proof of the presence of tryptic and ereptic ferments in the fungus, the next logical step in sequence was to ascertain whether amidases were present, for protein digestion normally proceeds further than to the peptone stage and results in the amino acids, which, digested by amidases, yield ammonia and hydroxy-acids.

In the lower fungi these desamidizing enzymes have been found by many workers. Butkewitsch ('03) found by growing cultures of *Aspergillus, Penicillium,* and certain species of *Mucor* on liquid media, containing proteins that ammonia is liberated; and in the following year Shibata ('04) found in a "Dauerpräparat" of the mycelium of *Aspergillus niger* an enzyme which split ammonia from different nitrogen-containing substances, while Pringsheim ('08) found the same enzyme present in "Acetonedauerhefe." Dox ('10) found that the enzyme preparation from *Aspergillus niger* and *Penicillium Camemberti* showed the power to split ammonia from asparagin and urea. Reed ('13) found very similar results by the action of the enzyme powder from *Glomerella rufomaculans* on asparagin and alanin. The only record of urease from one of the higher fungi was that reported by Kikkoji ('07) in *Cortinellus edodes.*

In the experiments reported in the following tables the enzyme dispersions from both the mycelium and sporophores and also the fungous powder from both tissues were used. As substrates 50 cc. of 1 per cent solutions of asparagin, acetamid, and urea were used. Ten cubic-centimeter portions of the enzyme dispersions were used in some cases, while an equivalent weight of the fungous meal was used where the enzymes were not extracted and precipitated. Autoclaved controls, as well as the substrates alone, were set up for each

series, and toluol was used as an antiseptic in all cases. Each experiment was set up in a gas-washing bottle, which was fitted with rubber tubes securely stoppered. These washing bottles were incubated at 25–30°C. for 20 days, when the ammonia was determined by the Folin method. Friedrich's improved gas-washing bottles containing 250 cc. of N/50 HCl were used for the collection of the ammonia. Air was drawn through for 1½ hours by means of a Richards' suction pump,

TABLE XII

AMIDASE ACTION IN THE MYCELIUM OF LENZITES SAEPIARIA

Substrate	Form of enzyme material	Nitrogen as ammonia set free	Net nitrogen set free
		mg.	mg.
Urea	Enzyme dispersion	2.10	0.28
Urea	Enzyme dispersion (autoclaved)	1.82	.....
Urea alone	.....	1.12	.....
Urea	Meal	23.55	22.57
Urea	Meal (autoclaved)	0.98	.....
Asparagin	Enzyme dispersion	1.40	0.00
Asparagin	Enzyme dispersion (autoclaved)	1.04	.....
Asparagin alone	.....	0.14	.....
Asparagin	Meal	0.21	0.07
Asparagin	Meal (autoclaved)	0.00	.....
Acetamid	Enzyme dispersion	1.12	0.00
Acetamid	Enzyme dispersion (autoclaved)	1.12	.....
Acetamid	Meal	0.14	0.14
Acetamid	Meal (autoclaved)	0.00	.....
Acetamid alone	.....	0.00	.....

TABLE XIII

AMIDASE ACTION IN THE SPOROPHORAL TISSUE OF LENZITES SAEPIARIA

Substrate	Form of enzyme material	Nitrogen as ammonia set free	Net nitrogen set free
		mg.	mg.
Urea	Enzyme dispersion	5.46	—
Urea	Enzyme dispersion (autoclaved)	6.16	.....
Urea alone	.....	6.16	.....
Urea	Meal	18.34	12.18
Urea	Meal (autoclaved)	5.88	.....
Asparagin	Enzyme dispersion	1.89	0.91
Asparagin	Enzyme dispersion (autoclaved)	0.98	.....
Asparagin	Meal	2.24	1.12
Asparagin	Meal (autoclaved)	1.12	.....
Acetamid	Enzyme dispersion	2.03	1.75
Acetamid	Enzyme dispersion (autoclaved)	0.28	.....
Acetamid	Meal	0.28	—
Acetamid	Meal (autoclaved)	0.84	.....

then duplicate portions of the collection acid were titrated against N/50 NaOH. Alizarin red was used as an indicator. Tables XII and XIII show the results obtained.

It is interesting to notice that urease is the only active enzyme in the fungus which produces desamidation, and that this enzyme was not extracted with water. Pringsheim ('08) has shown that the amidases of yeast do not pass out with the water extract but are tenaciously held by the protoplasm. The same may be the case with urease of *Lenzites,* and since we assume that the enzymes are protein-like bodies it is possible that urease in this case is not like the albumins, which are water-soluble. It may be a globulin, soluble in neutral saline solutions, or glutelin, soluble in weak alkali.

It is again of interest here to notice that the enzyme is much more active in the mycelial than in the sporophoral tissue, even without considering the amount of sawdust present in the mycelial meal. Of course, here, as in other plants, it is not possible to connect the presence of urease with any useful function in the metabolism of the fungus. With our present knowledge of desamidation in plants the biological importance of urease remains unknown.

HIPPURICASE

The ability of the lower fungi to bring about the splitting of hippuric acid by enzyme action was first noticed by Shibata ('04) in the case of *Aspergillus niger.* Some years later Dox ('09) demonstrated the presence of hippuricase in other species of fungi, namely, *Penicillium Camemberti, P. chrysogenum,* and *P. brevicaule,* and he also confirmed Shibata's results on *Aspergillus niger.* The enzyme preparation was the ground fungous mycelium after it had been dried by the usual "Acetondauerhefe" method. His method of determining the amount of hippuric acid hydrolyzed is given in a later paper (Dox, '10). After hydrolysis by the enzyme the hippuric acid solution, which was made up in weak sodium hydroxide, was mixed with the calculated amount of sulphuric acid to combine with the sodium. This was shaken with petroleum ether which dissolves out the benzoic acid. The

latter crystallizes when the petroleum ether is evaporated, and the crystals, after recrystallization from water, melted at 121°C. and had the appearance of benzoic acid. In the controls no residue was obtained. The hydrolysis in the case of *Penicillium Camemberti* was 76 per cent.

In 1912 Kossowicz found that enzyme preparations of *Aspergillus niger, Mucor Boidin, Phytophthora infestans, Isaria farinosa, Botrytis Bassiana,* and *Cladosporium herbarum* in every case brought about the destruction of hippuric acid. As one of the reaction by-products he identified ammonia, but in no case did he state in how great quantities the ammonia was formed. Reed ('13) found that an enzyme powder prepared from *Glomerella rufomaculans* showed the presence of hippuricase after incubation for one week.

In 1913 Dox and Neidig applied Sörensen's formaldehyde-titration method for the determination of the acidity of amino acids to the hippuric acid hydrolysis. The method is founded on the reaction between formaldehyde and the primary amino group. Hippuric acid has no primary amino group, but after hydrolysis the primary amino group of the glycocoll split off may be neutralized with formaldehyde, leaving the carboxyl unchanged to be titrated against an alkali. In this case Dox and Neidig used N/10 $Ba(OH)_2$. They grew cultures of *Aspergillus niger, A. clavatus, A. fumigatus, Penicillium expansum, P. Roqueforti,* and *P. Camemberti* on a nutrient solution. The cultures were grown for 1, 2, 3, and 4 weeks, the juice pressed out after grinding the mycelium and used as an enzyme preparation. In all of these fungi hippuricase was found, as well as in taka-diastase (*Aspergillus Oryzae*). The age of the mycelium had little influence on the production of hippuricase. Titrations for free ammonia showed that in the cultures 3 and 4 weeks old there were slight amounts, if any, of ammonia, and a secondary reaction, or the splitting of glycocoll, is improbable.

Our experiments with the meal from the mycelial and sporophoral tissues of *Lenzites* were carried out in the same way as those described by Dox ('10). Fifty cubic-centimeter quantities of the substrate were used, and the flasks were incubated

at 25°C. for 2 weeks. After this period the benzoic acid was dissolved out with petroleum ether, dried, and then recrystallized from water. From 50 cc. of a 1 per cent solution of hippuric acid were obtained 0.24 grams of benzoic acid, or there was 65 per cent hydrolysis. The melting point was found to be 126°C. Since the melting point of hippuric acid is 187°C. and that of benzoic acid is 121°C., this was regarded as evidence that the crystals were benzoic acid.

NUCLEASE

The presence of nuclease has been demonstrated in various divisions of the plant kingdom. It performs an important function in decomposing the nucleic acids of plant cells, especially in germinating seeds or wherever dissimilation is carried on. In the fungi nuclease has been found both in the lower and higher forms. Iwanoff ('03) studied the effect of cultures and enzyme extracts of *Aspergillus niger* and *Penicillium glaucum* on nucleic acid, and observed that both species produced the purin bases and phosphoric acid in the substrate. He claims that the nuclease is distinct from the proteolytic enzymes, for his enzyme extract would not liquefy gelatin. Dox ('10) found that the nuclease of *Penicillium Camemberti* is formed irrespective of the presence of nucleic acid in the culture medium. Kikkoji ('07) expressed the juice from an agaric, *Cortinellus edodes,* and 25 cc. of this in 150 cc. of a $2\frac{2}{3}$ per cent solution of the sodium salt of nucleic acid produced 28.7 mg. of phosphorus pentoxide in 5 days' digestion. He considered this action due to nuclease, the juice being thermolabile.

In my work with *Lenzites saepiaria* a 1 per cent solution of phyto-nuclein from yeast was prepared by dissolving the phyto-nuclein in N/20 sodium hydroxide and then neutralizing. To 25 cc. of this solution 5 cc. of the enzyme dispersion were added with toluol as an antiseptic. Controls were set up by adding 5 cc. of autoclaved dispersion to the nuclein solution, and water controls made by adding 5 cc. of distilled water to the nuclein. This plan was followed both for mycelial and sporophoral dispersions. The flasks were incubated at

25–30° C. for 21 days, after which they were titrated for phosphoric acid which was calculated as phosphorus pentoxide according to the uranium acetate method described by Hawk ('12, p. 413). One cubic centimeter of the solution of uranium acetate used was calculated to be equivalent to 4.65 mg. of phosphorus pentoxide. Two cubic centimeters of a solution of sodium acetate were added to 10 cc. of the filtered substrate to be titrated. This was brought to a boil and titrated

TABLE XIV

NUCLEASE ACTIVITY IN LENZITES SAEPIARIA

Amount of enzyme dispersion used with 25 cc. of 1 per cent nuclein	Free H_3PO_4 as P_2O_5 after 21 days		Net P_2O_5 in 25 cc. of substrate	
	Mycelium	Sporophore	Mycelium	Sporophore
	mg.	mg.	mg	mg.
5 cc. enzyme dispersion	40.11	59.31	28.49	37.83
5 cc. enzyme dispersion (autoclaved)	11.62	22.08	.....	.....
5 cc. distilled water	9.89	.....	.....	.....

while hot. Potassium ferrocyanide was used as an indicator. Table XIV shows the results of these experiments, the figures given being the averages of duplicate experiments which were run in all cases.

These results demonstrate the presence of nuclease both in the mycelial and sporophoral tissues of *Lenzites saepiaria*. However, no quantitative comparison can be drawn, for the mycelial dispersion was made from the mycelial mat in sawdust. Compared with the results obtained by Kikkoji, the sporophoral dispersion is not so active as that in *Cortinellus*. This may be due to the fact that he used a more concentrated substrate and the juice of the fresh fungus direct.

The fact that phyto-nuclein, an alpha-nucleoprotein, was used as a substrate, and that this was broken down to phosphoric acid is a definite control on our results illustrating tryptic enzymes. The nucleoprotein must first be broken down by a nucleinase, which, according to the consensus of opinion, is a tryptic ferment. It is only after this enzyme has acted that the nucleic acid is free to be acted upon by nuclease.

PROTEASE

Proteolytic enzymes have been commonly demonstrated in the filamentous fungi, especially *Aspergillus* and *Penicillium,* but in the higher forms they are not so well known. The first to discover protein-digesting enzymes in the *Basidiomycetes* were Bourquelot and Hérissey ('95) who found that pieces of the white of an egg, which had been cooked for 10 minutes on a water bath, were changed when placed in the juice expressed from sporophores of *Polyporus sulphureus.* The solution gave a slight biuret reaction after incubating at 29–30° C. for 21 hours. Hjort ('96) found in the sap from the sporophores of *Pleurotus ostreatus* a tryptic ferment capable of digesting fibrin. It worked best in acid solutions and produced leucin, tyrosin, and tryptophan. The naturally acid watery extract of the sporophores of *P. sulphureus* readily digested fibrin, but if neutralized or made alkaline it did not act at all. The expressed juice, weakly acidified with hydrochloric acid or oxalic acid, digested fibrin as well as the original extract alone. After 12 hours of digestion the action was carried to peptones only. There were no amino acids present.

In 1898 Bourquelot and Hérissey investigated the same action of the expressed juice of the sporophores of *Amanita muscaria,* and found it to digest nearly all of the caseinogen of skimmed milk in 4 days, after which tyrosin was present in the solution. Kohnstamm ('01) investigated the proteases of *Armillaria mellea, Merulius lacrymans,* and *Polyporus squamosus.* The expressed juice from the sporophores of *Armillaria mellea* liquefied neutral thymol-gelatin to the extent of 1 mm. in depth in 10 days. The gelatin tubes were 8 mm. in diameter. Both the mycelium and sporophores of *Merulius lacrymans* were used. The juice from both was equally active in liquefying gelatin, about 8 mm. in 10 days or equivalent to 0.6 cc. The active principle is thermolabile. In a 0.2 per cent solution of hydrochloric acid the extract digested fibrin to peptone but not to amino acids, while in 0.2 per cent sodium carbonate solution there was no digestion of fibrin. The juice of sporophores of *P. squamosus,* collected

in January and March, liquefied gelatin at the rate of 1 mm. per day for 30 days. There was the same action on fibrin as related above for *Merulius lacrymans.*

Vines ('03) found by allowing crushed sporophoral tissue of *Agaricus campestris* to act on fibrin for 22 hours that there was a complete digestion to amino acids, i.e., the tissue is able to peptonize fibrin and digest the peptones. Delezenne and Mouton ('03, '03[a]), a little later in the same year, secured widely different results. From the dried fruiting bodies of *Agaricus campestris, Amanita muscaria, A. citrina,* and *Hypholoma fasciculare* they made extracts with 0.8 per cent sodium chloride, using chloroform or toluol as antiseptics. The extracts thus prepared from all of these species converted peptone to amino acids, digested gelatin and casein, but would not peptonize fibrin. These results of Delezenne and Mouton seemed so contradictory to the observations of previous workers that Vines ('04) made further experiments to test their accuracy.

For this work the ground pulp of the sporophores of *Agaricus campestris,* with the lamellae removed, was used. Providing the sporophores were mature the digestion of fibrin was evident. However, when a watery extract of the pilei was used the results were less certain, but in other experiments Vines found that extracts made with 2 per cent sodium chloride from fresh and dried sporophores actively digested fibrin in 1 per cent toluol or 0.2 per cent hydrocyanic acid. Since he found that boiled fibrin was not digested by these extracts, he suggests that the negative results of Delezenne and Mouton must be due to this error. Thus the extracts of *A. campestris,* prepared by Vines, contained an enzyme capable of peptonizing fibrin and converting the peptones and albumoses to amino acids. From this he concludes that there are two distinct proteases present, the one trypsin, the other erepsin.

Buller, in 1906, confirmed the results obtained by Kohnstamm in 1901 on the presence of proteases in the sporophores of *P. squamosus.* Kikkoji ('07) demonstrated the presence

of a protease in the sporophores of *Cortinellus edodes*. It acted in neutral or alkaline solutions.

Rumbold ('08), in cultural studies on various wood-destroying fungi, investigated the action of 13 of them on gelatin of the following constitution: 2½ per cent Liebig's beef extract; 2½ per cent malt extract; 10 per cent gelatin. The reaction was adjusted in one lot by use of sodium carbonate and in another by the use of sodium hydroxide. She found that *L. saepiaria* was the only one to liquefy gelatin, and this only when sodium carbonate was used to readjust the reaction of the medium.

Experiments were conducted using various substrates such as gelatin, albumin, casein, legumin, peptone, and fibrin. The enzyme preparations and fungous meal were used in some cases, while in others the growing fungus was utilized.

Action on gelatin.—A 10 per cent gelatin was prepared in the same way as that used by Rumbold ('08), cited above. The reaction was adjusted with sodium carbonate and sodium hydroxide, and poured plates prepared and inoculated with mycelium of *Lenzites*. After a growth of 4 days a circle of gelatin 1.2 cm. in diameter was liquefied in the region of the inoculum, but this only in those plates neutralized with sodium carbonate, while there was no liquefaction in those neutralized with sodium hydroxide. In the latter the mycelium had penetrated the gelatin to some extent. Gelatin in the form of Mett's tubes was digested by the enzyme dispersion of the mycelium, but sodium hydroxide did not show the same inhibiting effect as mentioned above. Negative results were obtained with the sporophoral dispersion. These results are quite in accord with experiments of other workers who have investigated the influence of the reaction of the medium on the growth of timber-destroying fungi. In this case the results suggest that there is an effect of alkalis on the metabolism of the fungus, i. e., that the secretion of proteolytic enzymes by the living organism is checked by the toxic effect of such active alkalis as sodium hydroxide, but when once excreted they have no inhibitory effect on the enzyme action.

Action on albumin, casein, legumin, and peptone.—The proteolytic action of the enzymes of the sporophoral and mycelial dispersions was tested by means of various substrates, under acid, alkaline, and neutral conditions. One per cent solutions of albumin, casein as such, as well as in the form of commercial "nutrose," legumin, and peptone were prepared. Casein and legumin were dissolved in N/10 NaOH. Albumin was also used in the form of Mett's tubes.

To determine the tryptic action the biuret test was employed. In testing for peptone by the biuret test it is necessary to get rid of the native proteins, since these give a purplish blue coloration with alkaline copper sulphate, the purple blinding the fainter pink test for peptone. In order to do this ammonium sulphate is usually added in crystalline form to precipitate the higher proteins. The precipitate, however, is generally in such finely divided particles that it will not filter out with the filter papers commonly used. To overcome this difficulty the solution was filtered through bone black to remove the precipitate. The question arose whether the bone black might not absorb the peptone, and tests were made as follows: To a few cubic centimeters of 1 per cent casein solution was added a small bit of Witte peptone. Crystals of ammonium sulphate were added to precipitate the casein. After filtering through bone black the clear filtrate gave a pink color with sodium hydroxide and dilute copper sulphate.

The tryptophan test was employed in testing for the action of erepsin. Wherever a test for tryptophan was given, higher proteins being used as a substrate, there was a demonstration of tryptic action as well. The tryptophan test is the production of a pink color after the addition of a few drops of glacial acetic acid and then a few drops of strong chlorine water.

Experiments were set up using 10-cc. portions of the above-mentioned substrates in tubes. Two cubic centimeters of the enzyme dispersions were added to each tube, except the water controls. Toluol was used as an antiseptic. Each substrate was set up in series of neutral, acid, and alkaline cultures, the acidity and alkalinity being approximately N/200.

Where casein, legumin, and albumin were used as substrates there was no indication of digestion in either the mycelial or sporophoral dispersion. In no case was there positive proof of peptonization. Peptone, however, was peptolyzed in neutral, alkaline, and acid solutions. If any distinction can be made there was stronger indication of tryptophan in the acid and alkaline solutions than in neutral. Quantitative determinations were not made.

Action on fibrin.—The digestion of fibrin was determined by using the method described by Reed ('13). Fibrin was stained in 1 per cent Congo red, and the color fixed by immersion in hot water. When such fibrin is acted on by trypsin the red color is liberated into the solution. With this colored fibrin in water as a substrate, negative results were obtained with the mycelial and sporophoral dispersions. Toluol was used as an antiseptic. Another series of tubes was set up, using 6 grams of mycelial meal in 10 cc. of water and the colored fibrin as a substrate. In this case potassium cyanide was used as an antiseptic, and the results were positive. The color value in this case was difficult to judge, however, on account of the brown color imparted to the solution by the sawdust meal, but the tryptophan test confirmed the color liberation.

The question arose whether potassium cyanide is a better antiseptic than toluol, use of the first-mentioned having been recommended by Vines in certain cases. Later experiments were conducted, using the pure mycelium grown on carrot juice as a source of enzymes, while potassium cyanide, toluol, and thymol-chloroform were used as antiseptics. In this series pure fibrin in water was the substrate. In all of these except two, after digestion of two weeks, the tryptophan test was obtained, the exceptions being those of the autoclaved controls and water controls. The test was slightly more distinct where potassium cyanide was used as an antiseptic.

The results are sufficient to demonstrate the presence of both erepsin and trypsin in the mycelium, and at least erepsin in the sporophores of *L. saepiaria.*

RENNET

The property possessed by the juice of certain plants of causing milk to coagulate was known as early as the sixteenth century, notably in the case of *Galium verum.* According to Green ('93), this plant is still in use at the present day for the coagulation of milk in cheese-making. Green, Oppenheimer ('10), and Euler ('12) have comprehensively reviewed the literature on the occurrence of rennet in the higher plants. Oppenheimer ('10, p. 317) also lists certain bacteria, such as *Bacillus amylobacter, B. mesentericus* var. *vulgatus,* and *B. prodigiosus,* which cause the coagulation of milk. It has been observed by a few workers that rennet is present in certain fungi, especially *Aspergillus* and *Penicillium* (Oppenheimer, p. 317). Buller ('06) found this enzyme to be very active in the juice from the sporophores of *Polyporus squamosus,* and Bayliss ('08) reports it for *Polystictus versicolor.* In fact, the existence of rennet in the *Basidiomycetes* is considered general. Gerber ('09) has demonstrated its presence in 86 species. Of the wood-destroying forms, he examined *Stereum purpureum* Fr., *Polyporus adustus* Willd., *P. betulinus* Bull., *P. hispidus* Bull., *P. giganteus* Pers., *Trametes Bulliardi* Fr., *T. gibbosa* Pers., *T. suaveolens* L., *Daedalea borealis* Wahlb., *Hydnum repandum* L., *Armillaria mellea* Vahl, and *Lycoperdon piriforme* Schaeff.

Our experiments show that rennet is present in both the mycelium and sporophores of *L. saepiaria.* After incubating at 25–30°C. for 3 hours the coagulum was formed by the mycelial dispersion, but it took 7 hours to form a coagulum in the sporophoral dispersion. There was no coagulation in the boiled or water control after 20 hours, the toluol keeping it antiseptic. The results show that the rennet is more active in the mycelium than in the sporophores.

The biological importance of this enzyme in plants is entirely a mystery. There arises the supposition *a priori* that one has to do here with some peculiar phase of protease activity, since in animal life the activity of rennin seems to be closely linked with the proteases of the gastric and pancreatic juices.

OXIDASE AND CATALASE

Interest was first aroused concerning oxidases in higher fungi because of the discoloration of certain fungous tissues when exposed to the air. During the years 1895, '96, and '97 many papers appeared by Bourquelot, Bertrand, Hérissey, et al., dealing with the oxidases in the higher fungi. They found that laccase was widely distributed in the *Basidiomycetes,* and in the case of *Boletus cyanescens,* the bluing of injured spots was due to the laccase acting with the oxygen of the air on the boletol present in the tissues.

Bertrand ('96) showed that the crystalline chromogen in *Russula,* especially *Russula nigricans,* was tyrosin, and in the latter the tyrosin on exposure to the air was oxidized to melanin, a black substance. Tyrosinase in the tissues oxidized the tyrosin, causing the tissues to blacken.

Lutz ('12), investigating the oxidases in the stipes and pilei of *Gyromitra gigas* and *Disciotis perlata,* found tyrosinase present in both species, but in both a more marked action in the caps than in the stipes. Euler ('08) carefully investigated the catalase of *Boletus scaber.* There seemed to be a relation between the oil content of the fungus and the amount of catalase present, and the presence of a metal, like magnesium hydroxide, in the solution increased the catalytic action.

The literature concerning the function of oxidases in plants has been amply considered by Clark ('11), who makes special mention of the relation of oxidases to chromogens in the higher fungi and their possible aid in the respiration process.

In my experimental work on oxidases and catalase no quantitative determinations were made. In some instances the enzyme dispersions were used, in others the fresh tissues. Clark's ('10) methods were used, and guaiacum, alpha-naphthol, and paraphenylenediamine were used as indicators of oxidation. The mycelial extract was made from pure cultures of *L. saepiaria* grown on Thaxter's potato-hard agar. Ten grams of fresh fungous mat were ground with sand and treated with 100 cc. of distilled water. This extract (5 drops in 5 cc. of H_2O_2) caused a rapid evolution of gas, showing the presence of catalase. The sporophoral meal showed much

greater activity than that of the mycelium. Some sporophoral enzyme dispersion, added to hydrogen peroxide in an evaporating dish, showed active evolution of oxygen, but the mycelial dispersion treated in the same way gave none.

Oxidase action was shown by use of guaiacum and paraphenylenediamine but not with alpha-naphthol. The experiments were set up in the following way, and each series in duplicate: To 5 cc. of the fresh fungous extract were added 5 drops of hydrogen peroxide and 10 drops of the indicator. With the guaiacum a faint blue tinge was produced in 2 hours when the mycelial extract was used. When an extract from the dried sporophores was used in the same way the blue color was more distinct in 2 hours. The paraphenylenediamine gave a brownish color in about 6 hours both in the sporophoral and mycelial extracts.

Tyrosinase was demonstrated both in the sporophores and mycelium. The substrate used was a suspension of tyrosin in distilled water. To 10 cc. of this suspension 2 cc. of enzyme dispersion were added. There was no oxidation in the autoclaved controls, but in 16 hours the suspension containing mycelial dispersion had become a light gray, while that containing the sporophoral dispersion was a dark gray. Tyrosin when oxidized becomes black, but here where only partially oxidized it shows a gray color. The tyrosinase is more active in the fruiting bodies, as in the case of catalase and other oxidases.

Summary

In this paper there are considered some of the more important aspects of the physiology of a wood-destroying organism, *Lenzites saepiaria.*

1. The fungus was grown in pure cultures, and the characteristics of the mycelium and sporophores produced under cultural conditions are described.

2. Some factors influencing the growth and metabolism of the organism are discussed, and experimental results are given on the relations of the fungus to reaction of media, to water, and to oxygen. Special interest is attached to the in-

fluence of the resin content of the substratum on the growth of the fungus. A resin agar emulsion was prepared, and experimental data show that *L. saepiaria* will grow well on 50 per cent resin by weight, which is considerably more than is found in any coniferous wood. Growth is not entirely inhibited by 85 per cent resin.

3. The metabolism of the fungus was studied through the agency of enzyme action.

a. A standard method of extracting and isolating the enzymes was used, and enzyme preparations were made from vegetative and fruiting tissues. The methods commonly used of identifying the enzymes were employed.

b. Among the *esterases,* those acting on the esters of the lower fatty acids showed more active hydrolysis both in sporophoral and mycelial tissues than those acting on the neutral fats.

c. In the *carbohydrases,* positive evidence was obtained of the presence of *maltase, invertase, raffinase, emulsin, tannase, diastase, inulinase, ligninase, cellulase, hemicellulase,* and *pectinase,* while negative results were obtained for the presence of *pectase* and *lactase.*

d. The *cyto-hydrolyzing carbohydrases* were made a special study, together with their effects as demonstrated by microchemical observations on sound and decayed wood.

e. The action of *amidase* on asparagin and acetamid was practically negligible, while *urease* action was very decided when the fungous tissue was used instead of the enzyme preparations. The presence of *hippuricase* was also demonstrated.

f. The following additional enzymes have also been found: *nuclease, proteinases*—both tryptic and ereptic—*rennetase, oxidase,* and *catalase.*

4. A comparative study of the enzymes occurring in the sporophoral and mycelial tissues was made. As we would anticipate, this comparison shows that the important metabolic processes are carried on in the vegetative organs. In-

deed, wherever quantitative results were obtained, or where a comparison can be accurately made, as in the case of *diastase, invertase, tannase,* and *cellulase,* the greater activity is shown in the mycelium. An exception to this, however, is the *oxidases,* where the greater activity is in the sporophores.

Acknowledgments

The writer acknowledges his indebtedness to the Southern Pine Association, who through their appropriation of funds made this investigation possible, to the Missouri Botanical Garden for library and laboratory facilities, and to Professor B. M. Duggar and Dr. Hermann von Schrenk for their advice and helpful criticisms.

Bibliography

Appel, O. ('15). The relations between scientific botany and phytopathology. Ann. Mo. Bot. Gard. **2**: 275–285. 1915.

de Bary, A. ('86). Ueber einige Sclerotinien und Sclerotien-krankheiten. Bot. Zeit. **44**: 377–387, 393–404, 409–426, 433–441, 449–461, 465–474. 1886.

Bayliss, Jessie S. ('08). The biology of Polystictus versicolor (Fries). Jour. Econ. Biol. **3**: 1–24. *pl. 1–2.* 1908.

Bernthsen, A. ('12). A textbook of organic chemistry. pp. 1–720. 1912. [Edited and revised by J. J. Sudborough.]

Bertrand, G. ('96). Sur une nouvelle oxydase, ou ferment soluble oxydant, d'origine végétale. Compt. rend. Acad. Paris **122**: 1215–1217. 1896.

———, ('96a). Sur la présence simultanée de la laccase et de la tyrosinase dans la suc de quelques champignons. *Ibid.* **123**: 463–465. 1896.

Biffen, R. H. ('99). A fat-destroying fungus. Ann. Bot. **13**: 363–376. *pl. 1.* 1899.

———, ('01). On the biology of Bulgaria polymorpha Wett. *Ibid.* **15**: 119–134. *pl. 7.* 1901.

Bloor, W. R. ('14). A method for the determination of fat in small amounts in blood. Jour. Biol. Chem. **17**: 377–384. 1914.

Bourquelot, E. ('93). Les ferments solubles de l'Aspergillus niger. Soc. Myc. Fr., Bul. **9**: 230–238. 1893.

———, ('94). Présence d'un ferment analogue à l'emulsine dans les champignons et en particulier dans ceux qui sont parasites des arbres ou vivent sur le bois. *Ibid.* **10**: 49–54. 1894.

———, ('96). Des composes oxydables sous l'influence du ferment oxydant des champignons. Compt. rend. Acad. Paris **123**: 315–317. 1896.

———, ('96a). Action du ferment soluble oxydant des champignons sur les phénols insolubles dans l'eau. *Ibid.* **123**: 423–425. 1896.

———, ('97). Sur la présence générale, dans les champignons, d'un ferment oxydant agissant sur la tyrosine; sur le mécanisme de la coloration du chapeau de ces végétaux. Soc. Myc. Fr., Bul. **13**: 65–72. 1897.

————, et Bertrand, G. ('96). Les ferments oxydants dans les champignons. *Ibid.* **12**: 18–26. 1896.

————, ————, ('96a). Sur la coloration des tissus et du suc de certains champignons au contact de l'air. *Ibid.* **12**: 27–32. 1896.

————, et Harley, V. ('96). Sur la recherche et la présence de la tyrosine dans quelques champignons. *Ibid.* **12**: 153–156. 1896.

————, et Hérissey, H. ('95). Les ferments solubles du Polyporus sulfureus (Bull.). *Ibid.* **11**: 235–239. 1895.

————, ————, ('98). Recherche et présence d'un ferment soluble protéo-hydrolytique dans les champignons. Compt. rend. Soc. Biol. X. **5**: 972–974. 1898.

————, et Marchadier, L. ('04). Étude de la réaction provoquée par un ferment oxydant indirect (anaéroxydase). Compt. rend. Acad. Paris **138**: 1432–1434. 1904.

Brown, W. ('15). Studies in the physiology of parasitism. I. The action of Botrytis cinerea. Ann. Bot. **29**: 313–348. 1915.

Buller, A. H. R. ('05). The destruction of wooden paving blocks by the fungus, Lentinus lepideus Fr. Jour. Econ. Biol. **1**: 1–12. 1905.

————, ('06). The enzymes of Polyporus squamosus Huds. Ann. Bot. **20**: 49–59. 1906.

————, ('06a). The biology of Polyporus squamosus Huds., a timber-destroying fungus. Jour. Econ. Biol. **1**: 101–138. *pl. 5–9.* 1906.

————, ('09). Researches on fungi. pp. 1–287. *pl. 1–5. f. 1–83.* 1909.

Butkewitsch, W. ('03). Umwandlung der Eiweissstoffe durch die niederen Pilze im Zusammenhange mit einigen Bedingungen ihrer Entwickelung. Jahrb. f. wiss. Bot. **38**: 147–240. 1903.

Clark, E. D. ('10). The plant oxidases. pp. 1–111. 1910.

————, ('11). The nature and the function of the plant oxidases. Torreya **11**: 23–31, 55–61, 84–92, 101–110. 1911.

Cooley, J. S. ('14). A study of the physiological relations of Sclerotinia cinerea (Bon.) Schröter. Ann. Mo. Bot. Gard. **1**: 291–326. 1914.

Cousin, H., et Hérissey, H. ('08). Oxydation de l'eugénol par le ferment oxydant des champignons et par le perchlorure de fer; obtention de dehydrodieugénol. Compt. rend. Acad. Paris **146**: 1413–1415. 1908.

Cross, C. F., and Bevan, E. J. ('01). Researches on cellulose, I, 1895–1900. pp. 1–180. 1901.

————, ————, ('06). *Ibid.* II, 1900–1905. pp. 1–184. 1906.

————, ————, ('12). *Ibid.* III, 1905–1910. pp. 1–173. 1912.

Czapek, F. ('99). Ueber die sogenannten Ligninreaction des Holzes. Zeitschr. f. physiol. Chem. **27**: 141–166. 1899.

————, ('99a). Zur Biologie der holzbewohnenden Pilze. Ber. d. deut. bot. Ges. **17**: 166–170. 1899.

————, ('13). Biochemie der Pflanzen. **1**: 1–828. Jena, 1913. [See pp. 682–694.]

Davis, A. R. ('15). Enzyme action in the marine algae. Ann. Mo. Bot. Gard. **2**: 771–836. 1915.

Dean, A. L. ('03). Experimental studies on inulase. Bot. Gaz. 35: 24–35. 1903.

Delezenne, C., et Mouton, H. ('03). Sur la présence d'une kinase dans quelques champignons Basidiomycetes. Compt. rend. Acad. Paris 136: 167–169. 1903.

———, ('03a). Sur la présence d'une erepsine dans les champignons Basidiomycetes. *Ibid.* 136: 633–635. 1903.

Dox, A. W. ('09). The intracellular enzymes of lower fungi, especially those of Penicillium Camemberti. Jour. Biol. Chem. 6: 461–467. 1909.

———, ('10). The intracellular enzymes of Penicillium and Aspergillus. U. S. Dept. Agr., Bur. An. Ind. Bul. 120: 1–70. 1910.

———, und Neidig, E. ('13). Enzymatische Spaltung von Hippursäure durch Schimmelpilze. Zeitschr. f. physiol. Chem. 85: 68–71. 1913.

Duggar, B. M. ('05). The principles of mushroom growing and mushroom spawn making. U. S. Dept. Agr., Bur. Pl. Ind. Bul. 85: 1–60. *pl. 1–7.* 1905.

Euler, H. ('06). Zur Kenntnis der Katalase. Beitr. z. chem. Physiol. u. Path. 7: 1–15. 1906.

———, ('12). General chemistry of the enzymes. pp. 1–323. 1912. [Translation from German by Thos. H. Pope.]

Falck, R. ('02). Die Cultur der Oidien und ihre Ruckfuhrung in die hohere Fruchtform bei den Basidiomyceten. Beitr. z. Biol. d. Pflanzen 8: 307–346. *pl. 12–17.* 1902.

———, ('09). Die Lenzites-fäule des Coniferholzes. Möller's Hausschwammforschungen. Heft 3: 1–234. *pl. 1–7. f. 24.* Jena, 1909.

———, ('12). Die Merulius-fäule des Bauholzes. *Ibid.* Heft 6: 1–405. *pl. 1–17. f. 73.* Jena, 1912.

Ferguson, Margaret C. ('02). A preliminary study of the germination of the spores of Agaricus campestris and other basidiomycetous fungi. U. S. Dept. Agr., Bur. Pl. Ind. Bul. 16: 1–43. *pl. 1–3.* 1902.

Gerber, M. C. ('09). La présure des Basidiomycetes. Compt. rend. Acad. Paris 149: 944–947. 1909.

Grafe, V. ('04). Untersuchungen über die Holzsubstanz vom chemisch-physiologischen Standpunkte. K. Akad. Wiss., Wien, math.-naturw. Kl., Sitzungsber. 113: 253–295. 1904.

Green, J. R. ('88). On the germination of the tuber of the Jerusalem artichoke (Helianthus tuberosus). Ann. Bot. 1: 223–236. 1888.

———, ('93). On vegetable ferments. *Ibid.* 7: 83–137. 1893.

Hartig, R. ('78). Die Zersetzungscheinungen des Holzes der Nadelholzbäume und der Eiche. pp. 1–151. *pl. 1–21.* Berlin, 1878.

Hawk, P. B. ('12). Practical physiological chemistry. pp. 1–475. 1912.

Helbig, Dr. ('11). Notiz ueber den Cellulosegehalt von Eichenholz, welches durch Thelephora perdix verändert war. Naturwiss. Zeitschr. f. Forst- u. Landw. 9: 246–250. 1911.

Hjort, J. ('96). Neue eiweissverdauende Enzyme. Centralbl. f. Physiol. 10: 192–194. 1896.

Humphrey, C. J., and Fleming, Ruth M. ('15). The toxicity to fungi of various oils and salts, particularly those used in wood preservation. U. S. Dept. Agr., Bul. 227: 1–38. *pl. 1–4.* 1915.

Iwanoff, L. ('03). Ueber die fermentative Zersetzung der Thymo-nucleinsäure durch Schimmelpilze. Zeitschr. f. physiol. Chem. **39**: 31–43. 1903.

Jean, F. ('00). Die Bestimmung des Tannins und der Gallussäure. Ann. Chim. anal. appl. **5**: 134–140. 1900. [Chem. Centralbl. **1900**[1]: 1107–1108. 1900.]

Johnson, J. B. ('93). Timber physics. Investigations on long-leaf pine. 4. Results on mechanical tests. U. S. Dept. Agr., For. Div. Bul. 8: 22–31. *f. 11–16.* 1893.

Jones, L. R. ('05). The cytolytic enzymes produced by Bacillus carotovorus and certain other soft rot bacteria. Centralbl. f. Bakt. II. **14**: 257–272. 1905.

Kellerman, K. F., and McBeth, I. G. ('12). The fermentation of cellulose. *Ibid.* **34**: 485–494. *pl. 1–2.* 1912.

Kikkoji, T. ('07). Ueber das Vorkommen von einem Nucleinsäurespaltenden Fermente in Cortinellus edodes. Zeitschr. f. physiol. Chem. **51**: 201–206. 1907.

Knudson, L. ('13). Tannic acid fermentation. I. Jour. Biol. Chem. **14**: 159–184. *f. 1–2.* 1913.

————, ('13a). *Ibid.* II. Effect of nutrition on the production of the enzyme, tannase. *Ibid.* **14**: 185–202. 1913.

Kohnstamm, P. ('01). Amylolytische, glycosidspaltende, proteolytische und Cellulose lösende Fermente in holzbewohnenden Pilzen. Bot. Centralbl., Beih. **10**: 90–121. 1901.

Kossowicz, A. ('12). Die enzymatische Natur der Harnsäure- und Hippursäure-Garung. Zeitschr. f. Garungsphysiol. **1**: 121–123, 317–319. 1912.

Le Renard, A. ('12). Influence du milieu sur la résistance du Pénicille crustacé aux substances toxiques. Ann. Sci. Nat., Bot. IX. **16**: 277–336. 1912.

Lutz, M. L. ('12). Sur la présence dans le Gyromitra gigas et le Disciotis perlata de tyrosinase et d'un chromogene. Soc. Myc. Fr., Bul. **28**: 136–139. 1912.

Lyman, G. R. ('07). Culture studies on polymorphism of Hymenomycetes. Boston Soc. Nat. Hist., Proc. **33**: 125–209. *pl. 18–26.* 1907.

McBeth, I. G., and Scales, F. M. ('13). The destruction of cellulose by bacteria and filamentous fungi. U. S. Dept. Agr., Bur. Pl. Ind. Bul. 266: 1–52. *pl. 1–4.* 1913.

Mangin, L. ('92). Propriétés et réactions des composés pectiques. Jour. de Bot. **6**: 206–212, 235–244, 363–368. 1892.

————, ('93). *Ibid.* **7**: 37–47, 121–131, 325–343. *pl. 1–2.* 1893.

Miyoshi, M. ('95). Die Durchbohrung von Membranen durch Pilzefäden. Jahrb. f. wiss. Bot. **28**: 269–289. *f. 1–3.* 1895.

Münch, E. ('09). Untersuchungen über Immunität und Krankheitsempfänglichtkeit der Holzpflanzen. Naturwiss. Zeitschr. f. Forst- u. Landw. **7**: 54–75, 87–114, 129–160. *f. 1–5.* 1909.

Newcombe, F. C. ('99). Cellulose-enzymes. Ann. Bot. **13**: 49–81. 1899.

Oppenheimer, C. ('10). Die Fermente und ihre Wirkungen. pp. 1–606. 1910.

Pringsheim, H. ('08). Ueber Pilzdesamidase. Biochem. Zeitschr. **12**: 15–25. 1908.

Reed, H. S. ('13). The enzyme activities involved in certain fruit diseases. Va. Polytec. Inst., Agr. Exp. Sta. Rept. **1911-1912**: 51–77. 1913.

Richards, H. M. ('97). Die Beeinflussung des Wachsthums einiger Pilze durch chemische Reize. Jahrb. f. wiss. Bot. **30**: 665–688. 1897.

Rumbold, C. ('08). Beiträge zur Kenntnis der Biologie holzzerstörender Pilze. Naturwiss. Zeitschr. f. Forst- u. Landw. **6**: 81–140. *pl. 1. f. 1–22.* 1908.

Schellenberg, H. C. ('08). Untersuchungen ueber das Verhalten einige Pilze gegen Hemicellulosen. Flora **98**: 257–308. 1908.

von Schrenk, H. ('00). Two diseases of red cedar caused by Polyporus juniperinus n. sp. and Polyporus carneus Nees. U. S. Dept. Agr., Veg. Physiol. and Path. Bul. 21: 1–22. *pl. 1–7. f. 1–3.* 1900.

———, ('00a). Some diseases of New England conifers. *Ibid.* 25: 1–56. *pl. 1–15. f. 1–3.* 1900.

———, ('00b). A disease of Taxodium distichum known as peckiness, also a similar disease of Libocedrus decurrens known as pin-rot. Mo. Bot. Gard. Rept. **11**: 23–77. *pl. 1–6.* 1900.

———, ('01). A disease of the black locust (Robinia Pseudacacia L.). *Ibid.* **12**: 21–31. *pl. 1–3.* 1901.

———, ('03). A disease of the white ash caused by Polyporus fraxinophilus. U. S. Dept. Agr., Bur. Pl. Ind. Bul. 32: 1–20. *pl. 1–5.* 1903.

———, ('14). Two trunk diseases of the mesquite. Ann. Mo. Bot. Gard. **1**: 243–252. *pl. 6–7.* 1914.

———, ('14a). A trunk disease of the lilac. *Ibid.* 253–262. *pl. 8–9.* 1914.

Schwalbe, C. G. ('11). Die Chemie der Cellulose unter besonderer Berücksichtigung der Textil- und Zellstoffindustrien. Berlin, 1911.

Shaffer, P. A. ('14). On the determination of sugar in blood. Jour. Biol. Chem. **19**: 285–295. 1914.

Shibata, K. ('04). Ueber das Vorkommen von Amide spaltenden Enzymen bei Pilzen. Beitr. z. chem. Physiol. u. Path. **5**: 384–394. 1904.

Singer, M. ('82). Beiträge zur naheren Kenntnis der Holzsubstanz und der verholzten Gewebe. K. Akad. Wiss., Wien, math.-naturw. Kl., Sitzungsber. **86**: 345– 1882. (Cited by Grafe, '04, p. 357.)

Spaulding, P. ('11). The timber rot caused by Lenzites saepiaria. U. S. Dept. Agr., Bur. Pl. Ind. Bul. 214: 1–46. *pl. 1–4. f. 1–3.* 1911.

Vines, S. H. ('03). Proteolytic enzymes in plants. II. Ann. Bot. **17**: 297–316. 1903.

Ward, H. M. ('88). A lily-disease. *Ibid.* **2**: 319–382. *pl. 20–24.* 1888.

———, ('97). On the biology of Stereum hirsutum Fr. Roy. Soc. London, Phil. Trans. **189**^{2}: 123–134. *pl. 17–21.* 1897.

———, ('98). Penicillium as a wood-destroying fungus. Ann. Bot. **12**: 565–566. 1898.

Wehmer, C. ('12). Hausschwammstudien. I. Zur Biologie von Coniophora cerebella A. & Sch. Myc. Centralbl. 1: 2–10; *Ibid.* III. 2: 331–340. 1912.

———, ('14). *Ibid.* IV. Versuche ueber die Bedingungen der Holzansteckung und -Zersetzung durch Merulius. *Ibid.* 3: 321–332. *f. 1; Ibid.* V. 4: 241–252. *f. 1;* 287–299. *pl. 1–2.* 1914.

———, ('14a). Holzansteckungsversuche mit Coniophora, Trametes, und Polyporus. Ber. d. deut. bot. Ges. 32: 566–570. 1914.

————, ('14). Die chemische Wirkung des Hausschwamm auf die Holzsubstanz. *Ibid.* **32**: 601–608. 1914.

Weir, J. R. ('14). Notes on wood-destroying fungi which grow on both coniferous and deciduous trees. I. Phytopath. **4**: 271–276. 1914.

Westerdijk, Johanna ('15). Phytopathology in the tropics. Ann. Mo. Bot. Gard. **2**: 307–313. 1915.

Wolf, F. A. ('16). Citrus canker. Jour. Agr. Res. **6**: 69–99. *pl. 8–11. f. 1–8.* 1916.

Wolff, J. ('09). Sur quelques propriétés nouvelles des oxydases de Russula Delica. Compt. rend. Acad. Paris **148**: 500–502. 1909.

Explanation of Plate

PLATE 8

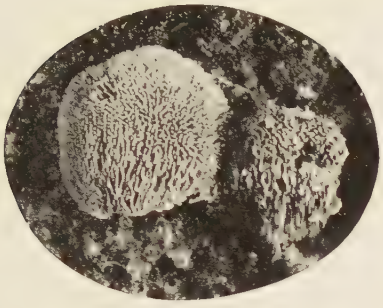
Figs. 1, 3, 4, 6, and 7. Sporophores of *Lenzites saepiaria* growing on sawdust in pure culture, and showing the thelephoroid, daedaloid, and irpiciform characters produced under cultural conditions.

Fig. 2. Sporophores *in situ* on blocks of *Pinus echinata* in pure culture.

Fig. 5. The lower surface of a sporophore borne on a horizontal surface of a cultural block. The hymenium is borne on typical Lenzites gills.

Figs. 8–12. Samples of pine after one year in culture under favorable moisture conditions, showing the typical internal decay.

Figs. 13–17. Samples of pine showing the superficial "scorching" after one year in culture, during which time the blocks were saturated with water.

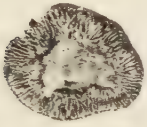


1

2

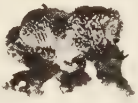
3

4



5

6



7

8

9

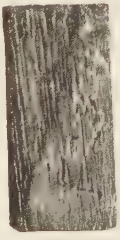
10

11

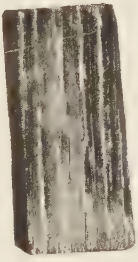
12

13

14



15



16

17

ZELLER—LENZITES SAEPIARIA

Explanation of Plate

PLATE 9

To illustrate the growth of *Lenzites saepiaria* on resin agar plates in Petri dishes of uniform size in 14 days.

Fig. 1. Control plate showing the growth on a Thaxter's glucose-potato-hard agar containing no resin.

Figs. 2–21. Showing the growth on 5–100 per cent resin agar, respectively (each plate increased by 5 per cent resin by weight), where Thaxter's glucose-potato-hard agar was used as a basis.

ZELLER—LENZITES SAEPIARIA

GENERAL INDEX TO VOLUME III

New scientific names of plants and the final members of new combinations are printed in **bold face** type; synonyms and page numbers having reference to figures or plates, in *italic;* and previously published scientific names and all other matter, in ordinary type.

A

Achorion Schönleinii, 268
Acrostalagmus albus, 6
Agrimonia, 309; *americana*, 313; *Eupatoria*, 313, 315, 316, 317, var. *americana*, 317, var. *glabra*, 313, var. *hirsuta*, 313, var. *mollis*, 315, var. *parviflora*, 313; gryposepala, 313; *hirsuta*, 313; microcarpa, 315; *mollis*, 316; parviflora, 317; *parviflora*, 313, 316; platycarpa, 315; polyphylla, 317; pubescens, 315; *pumila*, 315; rostellata, 313; *serrifolia*, 317; *striata*, 313; *suaveolens*, 317
Agrimonies, The Missouri, 309
Alternaria sp., cultures of, 279, 281
Amidases in Lenzites saepiaria, 489; in other fungi, 489
Apparatus, a note on the adaptability of the Folin micro-Kjeldahl, for plant work, 407
arachnoidea (*Thelephora*), 213
argillaceus (*Hypochnus*), 222
Ascomycetes, 253, 271; temperature relations of the, 51
Aspergillus, 253, 271; aviarius, 253, 271; bronchialis, 254, 271; candidus, 254, 271; *flavescens*, 254; flavus, 254, 271; fontoynonti, 255, 271; fumigatus, 254, 271; glaucus, 255, 271; malignus, 256, 272; niger, nitrogen fixation in, 423, 430; *nigrescens*, 254; nigricans, 256, 272; repens, 256, 272; Tokelau, 256, 272
atratum (Septobasidium), 334
atroruber (Hypochnus), 230
atroruber (*Zygodesmus*), 230
aurantiaca (*Tomentella*), 241
aurantiacus (Hypochnus), 241
avellaneus (Hypochnus), 225
Azotobacter chroococcum, nitrogen fixation in, 423, 431; vinelandii, nitrogen fixation in, 423, 431

B

Basidiomycetes, temperature relations of the, 53
bicolor (Hypochnus), 229
bicolor (*Zygodesmus*), 227
biennis (*Thelephora*), 213
botryoides (Hypochnus), 226
botryoides (*Thelephora*), 226
Botryosporium, 22; *pyramidale*, 22
Botrytis cinerea, 4
Burt, E. A. Pistillaria (subg. Pistillina) Thaxteri, Burt n. sp., 403; The Thelephoraceae of North America, VI, 203; VII, 319
Bush, B. F. The Missouri agrimonies, 309

C

Cabbage yellows, 25; and the relation of temperature to its occurrence, 25; causal organism of, 28; symptoms of, 27
canadensis (Hypochnus), 211
canescens (Septobasidium), 342
castaneum (Septobasidium), 330
Catalase in Lenzites saepiaria, 501; in other fungi, 501
Catalogue of the plants of Jasper County, Missouri, 345
Cellulase in Lenzites saepiaria, 474; in other fungi, 471
cervinus (Hypochnus), 232
chlorochaites (*Zygodesmus*), 219
Cineraria lyrata, 99
cinerascens (Hypochnus), 233
cirratum (Septobasidium), 334
Claudopus **subnidulans**, 195
Coniophora, 204; arida, 222
coriarius (Hypochnus), 228
Corticium, 204; *echinosporum*, 237; *ferrugineum*, 208; *fumosum*, 239; *fuscum*, 215; *isabellinum*, 222; *sulphureum*, 239; *thelephoroides*, 235; *umbrinum*, 213
Cotton root rot, disease of, 11
Cryptococcus, 263, 272; Corsellii, 263; degenerans, 263; farciminosus, 264; Gilchristi, 264; of Gotti & Brazzola, 263; granulomatogenes, 264; hominis, 264; linguae-pilosae, 264; lithogenes, 261, 265; niger, 265; Tokishigei, 265; tumefaciens, 262
Cyto-hydrolyzing enzymes, 465; effect of, on sound and decayed wood, 484

D

Davis, A. R.: A note on the adaptability of the Folin micro-Kjeldahl apparatus for plant work, 407; Duggar, B. M., and, Studies in the physiology of the fungi. I, Nitrogen Fixation, 413
Diastase in Lenzites saepiaria, 464; in other fungi, 464
Duggar, B. M.: Rhizoctonia Solani in relation to the "mopopilz" and the "vermehrungspilz," 1; The Texas root rot fungus and its conidial stage, 11; and Davis, A. R., Studies in the physiology of the fungi. I, Nitrogen Fixation, 413

E

echinosporum (*Corticium*), 237
echinosporus (Hypochnus), 237
elaeodes (*Hypochnus*), 218
Emig, W. H. The occurrence in nature of certain yeast-like fungi with reference to their possible pathogenicity in the higher animals, 243
Emulsin in Lenzites saepiaria, 462; in other fungi, 461
Endomyces, 259; albicans, 259, 272; tropicalis, 260
Enzyme activity in Lenzites saepiaria, 452
epigaeus (Hypochnus), 226
Esterases in Lenzites saepiaria, 455; in other fungi, 455

F

ferruginea (*Thelephora*), 208
ferruginea (*Tomentella*), 208
ferrugineum (*Corticium*), 208
ferrugineus (Hypochnus), 207
ferruginosa (*Tomentellina*), 212
ferruginosus (Hypochnus), 212
fibrillosus (Hypochnus), 238
flavovirens (Tomentella), 220
floridana (Thelephora), 214
Folin and Farmer, modification of Kjeldahl method of nitrogen determination by, 408; apparatus used in, 407, *412*
Förster method of determining nitrogen, 428
frustulosa (*Hymenochaete*), 337
frustulosum (Septobasidium), 337
fuligineus (Hypochnus), 232
fulvo-cinctus (*Hypochnus*), 228
fumigatum (Septobasidium), 340
fumosum (*Corticium*), 239
fumosus (Hypochnus), 239
Fungi: gill, New or interesting species of, from Missouri, 195; Studies in the physiology of the, I, 413, II, 439; yeast-like, The occurrence in nature of certain, with reference to their possible pathogenicity in the higher animals, 243
Fungi Imperfecti, 263, 272; temperature relations of the, 52
Fusarium, 25; conglutinans, 28, field observations of, 56, host relations of, 43, inoculation experiments with, 35, temperature relations of, 32, virulence of cultures of, 39; orthoceras, 30
fusca (*Odontia*), 239
fusca (*Thelephora*), 215
fusca (*Tomentella*), 215
fuscata (*Hypochnopsis*), 213
fuscatus (*Hypochnus*), 213
fuscum (*Corticium*), 215
fuscus (Hypochnus), 215

G

Gill fungi, New or interesting species of, from Missouri, 195
Gilman, J. C. Cabbage yellows and the relation of temperature to its occurrence, 25
Glenospora, 270, 272; Graphii, 270, 272
Glomerella Gossypii, nitrogen fixation in, 424, 431
Grandinia, 204; *coriaria*, 228; *tabacina*, 218
granosa (*Thelephora*), 227
granosus (*Hypochnus*), 227
granulosus (Hypochnus), 218
granulosus (*Zygodesmus*), 218
Greenman, J. M. A new Senecio from Jamaica, 201; Monograph of the North and Central American Species of the genus Senecio—Part II, 85
Gymnoascaceae, 267

H

Hemicellulase in Lenzites saepiaria, 479
Hippuricase in Lenzites saepiaria, 492; in other fungi, 491
hyalina (Pistillina), 405
Hymenochaete frustulosa, 337
Hymenomycete, the smallest known, 403
Hypochnus, 203; *argillaceus*, 222; **atroruber**, 230; **aurantiacus**, 241; **avellaneus**, 225; **bicolor**, 229; **botryoides**, 226; **canadensis**, 211; **cervinus**, 232; cinerascens, 233; **corium**, 228; **echinosporus**, 237; *elaeodes*, 218; **epigaeus**, 226; ferrugineus, 207; **ferruginosus**, 212; **fibrillosus**, 238; **fuligineus**, 232; *fulvo-cinctus*, 228; fumosus, 239;

fuscatus, 213; fuscus, 215; *granosus*, 227; **granulosus**, 218; isabellinus, 222; *leprosus*, 223; *obscuratus*, 216; **olivascens**, 220; **pannosus**, 223; **peniophoroides**, 234; **pilosus**, 221; rubiginosus, 209; *sitnensis*, 213; **sparsus**, 225; **spiniferus**, 218; **spongiosus**, 216; **subferrugineus**, 210; **subvinosus**, 231; tabacinus, 218; **thelephoroides**, 235; tristis, 213; **umbrinus**, 213; **zygodesmoides**, 236
Hypochnopsis fuscata, 213

I

Inulinase in Lenzites saepiaria, 488; in other plants, 488
Invertase in Lenzites saepiaria, 459
isabellinum (*Corticium*), 222
isabellinus (Hypochnus), 222

J

jamaicaense (Septobasidium), 333
Jasper County, Missouri, description of, 349; plants of, 359
Jola, 319

K

Kjeldahl method of determining nitrogen, the Folin modification of the original, 407

L

Lactase in Lenzites saepiaria, 458
Langloisii (Septobasidium), 335
Lenzites saepiaria Fries, 439; growth of, on resin agar plates, *512;* pine blocks decayed by, *510;* sporophores of, *510;* with special reference to enzyme activity, 439
Leprieurii (*Septobasidium*), 332
Lepidophyton, 257
leprosus (*Hypochnus*), 223
Ligninase in Lenzites saepiaria, 469; in other fungi, 466
lilacinum (Septobasidium), 343

M

Macro-Kjeldahl method of determining nitrogen, 410, 426
Macrosporium commune, nitrogen fixation in, 423, 430
Maltase in Lenzites saepiaria, 457
Moniliopsis Aderholdii, 2
"Mopopilz" and the "vermehrungspilz," Rhizoctonia Solani in relation to the, 1
Mortierella, 253, 271
Mucor, 250, 270; cornealis, 250, 270; corymbifer, 250, 270; Mucedo, 251, 271; parasiticus, 251, 271; pusillus, 252, 271; racemosus, 252, 271; ramosus, 252, 271; Regnieri, 251, 271; septatus, 252, 271; Truchisi, 251, 271

N

Nitrogen fixation, 413; methods of determining amount of, 426; organisms used in experiments in, 423; results of experiments in, 429
Nuclease in Lenzites saepiaria, 493; in other fungi, 493

O

obscuratus (*Hypochnus*), 216
Odontia, 204; *fusca*, 239; *porriginis*, 268
olivacea β botryoides (*Thelephora*), 226
olivascens (Hypochnus), 220
olivascens (*Zygodesmus*), 221
Oospora, 266, 272; buccalis, 267; lingualis, 265; porriginis, 268; pulmonalis, 266; sp., culture of, 281; tonsurans, 268; of Trichophyton, 267
Otomyces purpureus, 256
Overholts, L. O. New or interesting species of gill fungi from Missouri, 195
Oxidases in Lenzites saepiaria, 501; in other fungi, 501
Ozonium, 11; *auricomum*, 11; *omnivorum*, 11

P

Palmer, E. J. Catalogue of the plants of Jasper County, Missouri, 345
Panaeolus **reticulatus**, 195, *200;* **rufus**, 196, *200;* **variabilis**, 197, *200*
pannosus (Hypochnus), 223
pannosus (*Zygodesmus*), 223
Patouillardii (Septobasidium), 332
Pectase in Lenzites saepiaria, 483; in other fungi, 481
Pectinase in Lenzites saepiaria, 483; in other fungi, 481
pedicellata (*Thelephora*), 323, 324, 327
pedicellatum (Septobasidium), 323
Penicillium digitatum, nitrogen fixation in, 423, 431; expansum, nitrogen fixation in, 423, 431
Peniophora, 204
peniophoroides (Hypochnus) 234
Phlebia vaga, 239
Phoma Betae, nitrogen fixation in, 423, 431

Phycomycetes, 250, 270; temperature relations of the, 49
Phymatotrichum, 22; **omnivorum,** 22, host plants of, 12, mycelium of, 18; pyramidale, 22
pilosus (Hypochnus), 221
Pinus echinata, 453; palustris, 453; Taeda, 453
Pistillaria **Thaxteri,** 406
Pistillina hyalina, 405
plumbea (Sebacina), 241
plumbescens (Sebacina), 241
Pluteus cervinus var. **caespitosus,** 199, *200*
Protease in Lenzites saepiaria, 497; in other fungi, 495
pseudopedicellatum (Septobasidium), 327
punicea (Thelephora), 229

R

Raffinase in Lenzites saepiaria, 460; in other fungi, 461
Rennet in Lenzites saepiaria, 500; in other plants, 500
retiforme (Septobasidium), 338
retiformis (*Thelephora*), 338
Rhinotrichum, 22
Rhizoctonia Solani in relation to the "mopopilz" and the "vermehrungspilz," 1
Rhizomucor parasiticus, 251; *septatus,* 252
Rhizopus, 253, 271; Cohnii, 253, 271; niger, 253, 271; nigricans, 252, 271
rubiginosa (*Tomentella*), 209
rubiginosus (Hypochnus), 209
rubiginosus (*Zygodesmus*), 209

S

Saccharomyces, 257; anginae, 257, 272; cerevisiae, culture of, 284; granulatus, 258, 272
Saccharomycopsis, 258, 272; guttulatus, 258, 272
Schizomycetes, temperature relations of the, 49
Schweinitzii (Septobasidium), 324
Sclerotinia, 5
Sebacina plumbea, 241; **plumbescens,** 241
Senecio, A new, from Jamaica, 201; Monograph of the North and Central American Species of the genus—Part II, 85
Senecio, 85; acutidens, 178; *Adamsi,* 172; anacletus, 183, *192;* **aquariensis,** 144; *auleticus,* 102; aureus, 119, var. gracilis, 128, var. **semicordatus,** 129; *aureus,* 91, 129, var. *angustifolius,* 155, var. *Balsamitae,* 130, 149, 155, 159, > × *Balsamitae,* 129, var. *borealis,* 91, 96, 170, 174, 179, var. *compactus,* 179, var. *croceus,* 142, 144, 173, var. *discoidea,* 113, var. *discoideus,* 91, 96, var. *lanceolatus,* 130, var. *obovatus,* 108, 174, var. *pauciflorus,* 91, var. *subnudus,* 103; *balsamitae,* 148; *Balsamitae,* 155, 159, 167, var. *Crawfordii,* 139, var. *praelongus,* 159; Burkei, 136; *camporum,* 149; Cardamine, 116; *compactus,* 179; *condensatus,* 179; **conterminus,** 101; Crawfordii, 139; crocatus, 141, var. **Wolfii,** 143; *crocatus,* 145; cyclophyllus, 117; cymbalarioides, 174, var. **borealis,** 177, var. **streptanthifolius,** 177; *cymbalarioides,* 104, 173, 178, var. *diversilobus,* 171; debilis, 96; *densus,* 179; dimorphophyllus, 144; *discoideus,* 90, 91, 97; *Earlei,* 155; *Elliottii,* 108; *elongatus,* 91, 113; Farriae, 146; *fastigiatus,* 119; fedifolius, 90; **Fernaldii,** 90; flavovirens, 167, var. **thomsoniensis,** 169; *flavovirens,* 96; *flavulus,* 147, 167; *fulgens,* 167; **gaspensis,** 138; *Grayii,* 107; Hartianus, 147; *hesperis,* 102; hesperius, 102, *190; heterodoxus,* 144; **Hollickii,** 201; hyperborealis, 98; *hyperborealis* var. *columbiensis,* 100; idahoensis, 96; *indecorus,* 91; *Jonesii,* 173; laetiflorus, 170; *Lemberti,* 91; *Lindheimeri,* 114; *longipetiolatus,* 142; *Lyallii,* 101; *manitobensis,* 179; *Memmingeri,* 155; *Metcalfei,* 179; *microdontus,* 183; multnomensis, 169; *mutabilis,* 179; *nephrophyllus,* 97; Newcombei, 103; *oblanceolatus,* 179; obovatus, 108, var. **divisifolius,** 112, var. elongatus, 113, var. rotundus, 114, var. umbratilis, 115; *obtusatus,* 108; ovinus, 100; **Pammelii,** 118; pauciflorus, 91, var. fallax, 95; pauperculus, 159, var. **firmifolius,** 166; plattensis, 148; platylobus, 141; Porteri, 106; *prionophyllus,* 140; pseudaureus, 132, var. **flavulus,** 136; *pseudotomentosus,* 149; *pyroloides,* 102; *pyrrhochrous,* 142; quaerens, 140; **quebradensis,** 117; *remifolius,* 179; *renifolius,* 106; resedifolius, 99, var. columbiensis, 100; *resedifolius,* 98, 100; Robbinsii, 130; Rosei, 105, *190; rotundifolius,* 119; *rotundus,* 114; rubricaulis, 173; var. **aphanactis,** 174; *Rydbergii,* 167; *semicordatus,* 129; Smallii, 155; Soldanella, 107; *suavis,* 179; *subcuneatus,* 174; subnudus, 103; Suksdorfli, 172;

Swartzii, 201; toluccanus, 186, *194*, var. modestus, 188; *Toluccanus* var. *microdontus*, 183; *Tracyi*, 142; tridenticulatus, 179; *tussilaginoides*, 119; Wardii, 183, *190*; Willingii, 154; *Wootonii*, 183
Septobasidium, 319; atratum, 334; **canescens**, 342; **castaneum**, 330; **cirratum**, 334; frustulosum, 337; **fumigatum**, 340; **jamaicaense**, 333; Langloisii, 335; *Leprieurii*, 332; **lilacinum**, 343; **Patouillardii**, 332; pedicellatum, 323; **pseudopedicellatum**, 327; retiforme, 338; **Schweinitzii**, 324; Spongia, 339; **sublilacinum**, 331; **tropicale**, 326
sitnensis (*Hypochnus*), 213
sparsus (Hypochnus), 225
spiniferus (Hypochnus), 218
Spongia (Septobasidium), 339
Spongia (*Thelephora*), 339
spongiosa (*Thelephora*), 216
spongiosus (Hypochnus), 216
Sporotrichum, 268, 272; (Microsporon) Audouini, 266, 268; Furfur, 269; minutissimum, 269
Sterigmatocystis, 257, 272; nigra, 257, 272; pseudonigra, 257
Studies in the physiology of the fungi. I, Nitrogen Fixation, 413; II, Lenzites saepiaria, with special reference to enzyme activity, 439
subferrugineus (Hypochnus), 210
sublilacina (*Thelephora*), 331
sublilacinum (Septobasidium), 331
subvinosus (Hypochnus), 231
sulphureum (*Corticium*), 239

T

tabacinus (*Hypochnus*), 218
Tannase in Lenzites saepiaria, 463; in other fungi, 463
Temperature, the relation of: to the occurrence of cabbage yellows, 32; to the Ascomycetes, 51; to the Basidiomycetes, 53; to the Fungi Imperfecti, 52; to the Phycomycetes, 49; to the Schizomycetes, 49
Texas root rot fungus and its conidial stage, The, 11
Thaxteri (Pistillaria), 406
Thelephora, 204; *arachnoidea*, 213; *biennis*, 213; *botryoides*, 226; *ferruginea*, 208; floridana, 214; *fusca*, 215; *granosa*, 227; *olivacea* β *T. botryoides*, 226; *pedicellata*, 323, 324, 327; punicea, 229; *retiformis*, 338; *Spongia*, 339; *spongiosa*, 216; *sublilacina*, 331; *umbrina*, 213; *vinosa*, 215; *zygodesmoides*, 236
Thelephoraceae of North America, The, VI, 203; VII, 319
Toile, maladie de la, 4
Tomentella flavovirens, 220
Tomentella, 203; *aurantiaca*, 241; *cinerascens*, 233; *ferruginea*, 208; *fusca*, 215; *rubiginosa*, 209; *tristis*, 213
Tomentellina, 203; *ferruginosa*, 212
Torula neoformans, 261; sp., cultures of, 275, 281
tristis (*Hypochnus*), 213
tristis (*Tomentella*), 213
tropicale (Septobasidium), 326

U

umbrina (*Thelephora*), 213
umbrinum (*Corticium*), 213
umbrinus (Hypochnus), 213
Urease in Lenzites saepiaria, 489; in other fungi, 489

V

vaga (*Phlebia*), 239
"Vermehrungspilz" and the "mopopilz," the relation of Rhizoctonia Solani to the, 1
Verticillium Graphii, 270
vinosa (*Thelephora*), 215

Y

Yeast-like fungi, The occurrence in nature of certain, with reference to their possible pathogenicity in the higher animals, 243

Z

Zeller, S. M. Studies in the physiology of the fungi. II, Lenzites saepiaria Fries, with special reference to enzyme activity, 439
Zygodesmus, 204; *atroruber*, 230; *bicolor*, 227; *chlorochaites*, 219; *granulosus*, 218; *olivascens*, 221; *pannosus*, 223; *rubiginosus*, 209, 211
zygodesmoides (Hypochnus), 236
zygodesmoides (*Thelephora*), 236